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WILT DISEASES OF OKRA AND THE VERTICILLIUM-WILT PROBLEM

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INTRODUCTION

The investigation of the okra-wilt disease thus far reported has led to some confusion as to the cause of this malady. Atkinson (*3*)[2] mentions the fact that okra (*Abelmoschus esculentus*) is sometimes attacked by a disease similar to the wilt of cotton (*Gossypium herbaceum*). He states that a fungus for which he proposes the name "*Fusarium vasinfectum*" is invariably found in the vascular system of cotton and okra affected with this disease. Smith (*23*), in a more extensive study of the wilt diseases of cotton, watermelon (*Citrullus vulgaris*), and cowpea (*Vigna sinensis*), found an ascigerous fungus associated with the diseased plants. He regarded this new genus as the perfect form of *Fusarium vasinfectum* Atkinson, and renamed the latter fungus "*Neocosmospora vasinfecta*." Smith notes the occurrence of a wilt disease of okra, and regarding *N. vasinfecta* remarks (*p. 31*):

> It probably occurs also on okra, although the identification is not complete, depending solely on the character of the symptoms, on the presence of similar macroconidea and microconidia, and on the occurrence of the disease in the same localities, no cultures or cross inoculations of the okra fungus having been made and no perithecial fruits having been discovered.

Doubts as to the genetic relationship of *Neocosmospora vasinfecta* and *Fusarium vasinfectum* are expressed by Higgins (*12*), Butler (*5*), and Wollenweber (*31*, *32*). It appears from the inoculation and pure-culture work of the latter that *N. vasinfecta* Smith is to be regarded as a saprophyte entirely distinct from the vascular parasite *F. vasinfectum* Atk.

Clinton (*8*, *p. 268*) notes the occurrence of a wilt disease of okra in Connecticut which he considers as the same as that previously reported by Atkinson. The wilt of okra as it occurs in North Carolina is described

[1] Since the completion of these studies, the writer has been transferred to the position of Pathologist, Hawaiian Agricultural Experiment Station.

[2] Reference is made by number (italic) to "Literature cited," p. 544-546.

by Stevens and Wilson (*25*), with an additional statement of the disease by Wilson (*29*). They attributed this disease to *Fusarium vasinfectum.*

No inoculations of okra plants with *F. vasinfectum* are recorded by Atkinson, Clinton, Smith, or Stevens and Wilson. A species of Fusarium was found constantly associated with the wilt of okra, and the disease was regarded as the same as the cotton-wilt. Orton (*16*) states that in his experience okra has contracted the disease when planted in fields affected with cotton-wilt.

Wollenweber (*31*, *32*) reports a wilt disease of okra similar to that previously attributed to *Fusarium vasinfectum;* but *Verticillium albo-atrum* Reinke and Berthold, instead of the Fusariumu fungus, was constantly present in the vascular ducts. Successful inoculations were secured with *V. albo-atrum,* and the fungus was recovered from the wilting plants.

It would appear that there are two similar wilt diseases of this crop induced by two quite different vascular parasites. It was for the purpose of testing this latter hypothesis that the investigation herein recorded was undertaken. While okra as a crop is restricted in general to the home garden and is relatively of little importance, a study of the wilt diseases of this plant is of general significance to the whole problem of wilt disease.

THE GENERA VERTICILLIUM AND ACROSTALAGMUS IN RELATION TO WILT DISEASES

Verticillium albo-atrum was first described by Reinke and Berthold (*22*) in 1879 as the cause of a wilt disease of potato (*Solanum tuberosum*) in Germany. This appears to be the earliest record of species of Verticillium associated with wilt disease. The work of Reinke and Berthold was generally overlooked until the investigation of the leafroll (*Blattroll-krankheit*) and similar diseases of *S. tuberosum* brought it again to the attention of pathologists. Recently the presence of *V. albo-atrum* in wilting potato plants has been noted by several investigators: Appel (*2*), Spieckermann (*24*), Pethybridge (*18*), (*19*), Störmer (*26*), Wollenweber and Schlumberger (*34*), Wollenweber (*30*, *31*, *32*), Orton (*17*). Wollenweber (*31*, *32*) reports this organism as the cause of a wilt disease of a *S. tuberosum*, *S. melongena*, and *Abelmoschus* (*Hibiscus*) *esculentus*. A similar disease of snapdragon (*Antirrhinum* sp.) was described by Brown (*4*) and the causal fungus determined by the present writer as *V. albo-atrum*. *V. dahliae*, a species closely related to *V. albo-atrum*, is described by Klebahn (*14*) as the cause of a wilting of dahlias. Aderhold (*1*) also mentions a species of Verticillium in connection with thrombosis of currants (*Ribes* spp.—"*Johannisbeere*") and gooseberry (*Ribes* spp.—"*Stachelbeere*").

The causal organisms of a series of diseases of several host plants variously described as wilt disease, thrombosis, bluestem, etc., have been relegated by the respective authors to the genus Acrostalagmus. Owing

to the confusion existing in the genera Verticillium and Acrostalagmus, a discussion of the interrelations of these form groups is necessary at this time.

Among those writers who have obtained and described Acrostalagmus-like fungi may be cited the following: Van Hook (*27*) discusses a wilt disease of ginseng (*Panax quinquefolium*) which he found associated with a vascular-inhabiting fungus. It is said to closely resemble *Acrostalagmus albus* Preuss. Rankin (*20*) renamed the ginseng-wilt fungus "*Acrostalagmus panax*" Rankin, without giving a technical description of the fungus or stating reasons for the change. Whetzel and Rosenbaum (*28*), in mentioning this disease of ginseng, attribute it to a species of Acrostalagmus. Guéguen (*10*) describes a new species of Acrostalagmus causing a wilt disease of the China aster Reine-Marguerite (*Aster* sp.), and to this fungus he gave the name *A. vilmorinii*. A variety of this organism he later mentions (*11*) as associated with a disease of fruits of the cacao (*Theobroma cacao*). Lawrence (*15*) attributes a new disease of black raspberry (*Rubus occidentalis*)—that is, the bluestem disease—to a species of Acrostalagmus, for which he proposes the name "*Acrostalagmus caulophagus*." Rankin (*21*), in a preliminary report of a thrombotic disease of maple trees (*Acer* spp.), mentions that a species of Acrostalagmus is associated with the trouble.

Corda (*9, p. 15*) established the genus Acrostalagmus to accommodate an organism, *A. cinnabarinus*, which was said to differ from Verticillium by forming its spores in heads at the tips of the conidiophores. Hoffman (*13*) has rightly explained the complicated structure of the sterigma as represented by Corda, and likewise the collection in heads of the singly abscissed conidia. The conidia are held together by virtue of an hygroscopic slime, which takes up water in the presence of a sufficiently moist atmosphere, forming a sphere of water at the tip of each sterigma. In these water droplets the conidia are observed to float freely. With excess moisture the drops rupture and the conidia slip down the conidiophore. However, in the absence of moisture the conidia cling tenaciously to the tips of the sterigma in the form of irregular rounded masses of varying sizes. If such material is placed under a dry cover slip without being allowed to come in contact with the latter, and examined microscopically while a small water drop is brought into the vicinity of the dry spore head, the spore aggregate will be seen gradually to round up and the conidia to float more or less actively within the spherule (Pl. 17, B,D).

In the genera Acrostalagmus and Verticillium we now have the following contradictory and imperfect characterization and limitation of forms. In Verticillium the singly abscissed and characteristically singly borne conidia may adhere in the presence of moisture, forming terminal heads—that is, water droplets containing conidia. In Acrostalagmus the conidia, characteristically united in heads, soon separate if the humidity of the environment is in excess of the maximum for the moisture drops

to retain their form, leaving but one immature conidium on the sterigma tip, as in Verticillium.

Furthermore, in the genus Verticillium, characterized by singly borne or readily separating conidia, we have the anomalous condition of a section of the genus set aside for those species in which the conidia are held together by slime—that is, section Gliocephalum [1] Saccardo (1886). This section of the genus accommodates forms in which the conidia are united in slimy heads—that is, Acrostalagmus.

The fact that the work of Reinke and Berthold (*22*) was so generally overlooked is responsible for the confusion of the genera Verticillium and Acrostalagmus. These investigators studied *A. cinnabarinus*, on which Corda established his genus Acrostalagmus, and concluded that this form genus must be united with the older genus Verticillium Nees. They changed the name of Corda's fungus to *Verticillium cinnabarinum*. In view of the above, there seems to be no doubt that the genus Acrostalagmus Corda should be united with the genus Verticillium Nees. Klebahn (*14*) supports this view.

The species of Acrostalagmus, described as causing a vascular disease of ginseng, China aster, and black raspberry, may prove upon further work to be identical with each other and with *V. albo-atrum*, as proved in this paper, for the strains of the latter fungus isolated from okra, cotton, eggplant (*Solanum melongena*), and potato. Culturally, at least, the strains of the species of Acrostalagmus from ginseng and raspberry, in so far as they have been studied by the writer, are not to be distinguished from *Verticillium albo-atrum*. The organisms *A. vilmorinii* Guéguen and *V. dahliae* Klebahn, as described by their authors, hardly differ sufficiently from *V. albo-atrum* to be given specific rank. Possibly this is the better treatment of such related forms until their identity is established by careful cross-inoculation work with pure cultures. The minor cultural differences found by the writer in cultures of *V. albo-atrum* from different hosts are present in parallel cultures of the same strain. Strains of *V. albo-atrum* which are morphogically indistinguishable, isolated from different hosts, and capable of producing the same symptoms of disease by cross-inoculation, seemingly should be considered identical.

The available data on the several strains of Verticillium and Acrostalagmus thus far described as plant parasites are brought together in tabular form (Table I), in order that comparison may be readily made. The hypothetical identity of all of these strains, suggested by the similarity of this data, is strengthened if one consults and compares the descriptions by the several authors. The existing differences seem to be those of variety rather than of species.

[1] Saccardo's section Gliocephalum of the genus Verticillium (SACCARDO, P. A. SYLLOGE FUNGORUM. v. 4, p. 159. Patavii, 1886) is given as Gliocladium by Engler and Prantl (1900) apparently through error. (ENGLER, A., and PRANTL, K. NATURLICHEN PFLANZENFAMILIEN. Teil 1, Abt. 1**, p. 418, 432. Leipzig, 1900.)

TABLE I.—*Data of several species and strains of Verticillium and Acrostalagmus arranged for comparison*

Organism.	Conidia.		Sclerotia.		Sclerotial cells.		Length of conidiophore branches.
	Limits of size.	Average size.	Limits of size.	Average size.	Limits of size.	Average size.	
	μ.	μ.	μ.	μ.	μ.	μ.	μ.
V. albo - atrum strain 1717 from okra.	5.1 to 11 by 2.1 to 3.0.	6.8 by 2.4...	21 to 91	34 by 44	7 to 10	8.4 by 8.7	13.5 to 22.0
V. albo - atrum strain 2784 from potato.	4.2 to 9.3 by 1.7 to 4.2.	6.4 by 2.4...	31 to 70	45 by 54	5 to 10	8.2 by 8.2	.....
V. albo - atrum strain 1685 from eggplant.	5.1 to 8.5 by 2.1 to 4.2.	6.5 by 2.6...	31 to 87	51 by 51	.....	7.3 by 9.4	.....
V. albo - atrum strain 2985 from snapdragon.	.....	.....	28 to 70	39 by 57	3 to 15	.....	15.0 to 38.0
V. albo - atrum by Reinke and Berthold.	5.0 to 12.0 by 2.0 to 3.5.	.....	.....	.....	.....	.....	.....
V. albo-atrum as given by Klebahn.	4.0 to 6.0 by 1.5 to 2.5.	.....	.....	54	.....	.....	12.0 to 45.0
V. dahliae by Klebahn.	4.0 to 7.0 by 1.5 to 2.0.	.....	.....	50	5 to 6	.....	16.0 to 27.0
A. albus by Van Hook.	2.0 to 5.0 by 1.0 to 2.0.	.....	.....	.....	.....	.....	10.0 to 25.0
A. caulophagus by Lawrence.	3.0 to 7.0 by 2.0 to 3.0.	.....	.....	.....	7 to 12	.....	.....
A. vilmorinii by Guéguen from China aster.	5.0 to 7.0 by 2.5 to 3.0.	.....	20 to 70	50 to 60	.....	.....	.....
A. vilmorinii from cacao.	6.0 to 7.0 by 3.0 to 4.0.	.....	.....	None.	.....	.....	.....

For the reasons above set forth, it is evident that the genus Acrostalagmus must be united with the older genus Verticillium. In view of this condition, the following forms, if not identical with *V. albo-atrum*, must at least be regarded as belonging to the genus Verticillium: *A. albus* from ginseng-wilt disease, described by Van Hook (*27*) and renamed *A. panax* by Rankin (*20*); *A. vilmorinii* Guégen, from the China aster and the fruits of the cacao; and *A. caulophagus* Lawrence, the cause of the bluestem disease of black raspberry. Of the remaining 12 imperfectly characterized and apparently saprophytic species of the genus Acrostalagmus some are no doubt identical with species of Verticillium, and are just as incompletely delineated. The ubiquitous *V. lateritium* Berk., commonly present on decaying potatoes, is possibly the same as *V. innabarinum* (Corda) Reinke and Berthold.

FUSARIUM VASINFECTUM AND VERTICILLIUM ALBO-ATRUM, CAUSES OF THE WILT DISEASES OF OKRA

FUSARIUM VASINFECTUM

The species of Fusarium from okra- and cotton-wilt considered in this work are regarded as identical with each other and with the species of Fusarium isolated from "frenching" cotton by Atkinson (*3*) and named by him "*F. vasinfectum*." The cross-inoculation work herein recorded proves the casual relation of *F. vasinfectum* to the wilt disease of okra,

and establishes the pathologic identity of the cotton- and okra-wilt strains beyond reasonable doubt.

Certain strains of the species of Fusarium causing cotton-wilt were observed by Wollenweber (*31*, *32*) to produce an aromatic odor (lilac) when cultured on starchy media such as rice; other strains less commonly isolated lacked this property. These latter strains were designated "*F. vasinfectum* var. *inodoratum*" by Wollenweber. As a further indication of the identity of the species of Fusarium on okra with the species of Fusarium on cotton, it should be noted that both the odor-forming and the non-odor-forming strains have been isolated several times from okra. While the ability to generate this odor is of doubtful specific value, since other species of the section Elegans (*Wollenweber*, *32*) possess this property, and this ability has been observed to be lost in culture (*Carpenter 7*, *p. 206*), the fact that the species of Fusarium from okra and cotton agree in this character is significant.

Normal [1] cultures of this species of Fusarium develop in 1 to 3 weeks at room temperature (Pl. A). The best results are secured with plant stems, potato cylinders, and other vegetable media. Morphologically *F. vasinfectum* is scarcely distinguished from the other vascular parasites of the section Elegans of this genus.

Potato-cylinder cultures (Pl. A) develop an ocherous-salmon-colored pionnotes with 3- to 5-septate conidia (Pl. 17, L-M). Blue-gray sclerotia, similar to those of *F. oxysporum* Schlecht. (*7*, *Pl. A*, *1*), are generally present on this medium. The slight violet color of the upper part of the pionnotes as represented in Plate A, 3, has never been seen in other closely related species and is possibly of differential value. Stems of *Melilotus alba* and *Gossypium* sp. are useful in developing the sporodochia, which are likewise of an ocherous-salmon color. The plate of *F. oxysporum* in an earlier paper (*7*, *Pl. A*, *2*, 5) illustrates stem cultures of *F. vasinfectum* equally well. On steamed-rice medium a more or less brilliant red color soon appears, later becoming tinged with various shades of purple and blue, especially in subdued light. Normal conidia are not usually present in rice cultures, the value of this medium being the color reaction and the formation of an aromatic substance with an odor suggesting lilac (*7*, *p. 206*). Chlamydospores (Pl. 17, I) are formed in large numbers on this medium.

The following measurements show the size and percentage of the variously septate, normal, conidia (Pl. 17, L, M) found in strains of *F. vasinfectum* from okra and cotton:

F. vasinfectum, strain 2709, isolated from okra. Culture, 27-day-old stem of *Melilotus alba*, without pionnotes. Normal triseptate conidia, 60 per cent. Limits of size: 25.5 to 40.8 by 4.2 to 5.1 μ. Largest normal triseptate conidium, 40.8 by 5.1 μ.; smallest, 25.5 by 4.2 μ. Average

[1] For a discussion of the idea "normal" and other special terms as used in relation to species of Fusarium, see Wollenweber (*33*, *p. 255-257*).

size of 10 normal triseptate conidia, 32.5 by 4.6 μ. One-septate conidia, 20 per cent. Abnormal conidia and microconidia, 20 per cent.

Normal conidia on rice culture 2½ months old: Triseptate, 23.8 to 30.0 by 4.0 to 5.0 μ. Five-septate rare, 56.0 by 3.6 μ.

F. vasinfectum strain 3203 from okra. Pionnotes on a 25-day-old stem culture of *Melilotus alba*. Limits of size of 28 normal triseptate conidia: 23.8 to 34.0 by 3.8 to 4.2 μ. Average size, 28.4 by 3.9 μ. Largest triseptate conidium, 34.0 by 4.2 μ. Smallest triseptate conidium, 23.8 by 3.8 μ.

F. vasinfectum strain 3242 from okra. Normal triseptate conidia, 34.0 to 41.0 by 3.4 to 5.0 μ. Four-septate conidium 40.8 by 4.2 μ.

F. vasinfectum var. *inodoratum* strain 3257 from okra. Thirty-four-day-old *Melilotus* stem culture with pionnotes. Normal triseptate conidia 60 per cent. Limits of 17 spores, 32.3 to 45.9 by 3.4 to 4.8 μ. Average, 37.4 by 4.2μ. Four-septate, 35 per cent. Limits of 13 spores, 34.0 to 44.2 by 4.2 to 4.8 μ. Average, 39.0 by 4.2 μ. Five-septate, 5 per cent. Limits of four spores, 37.4 to 45.9 by 4.2 to 4.9 μ., average four spores 42.0 by 4.4 μ.

F. vasinfectum var. *inodoratum* strain 3258 from okra. Thirty-four-day-old pionnotes culture. Normal triseptate conidia 76 per cent. Limits of 9 spores, 27.2 to 41.6 by 3.4 to 4.6 μ. Average, 34.0 by 4.2 μ. Four-septate conidia, 19 per cent. Limits of 13 spores, 35.7 to 42.5 by 3.4 to 5.0 μ. Average, 37.8 by 4.1 μ. Five-septate, 5 per cent. Limits of 6 spores, 34.0 to 45.9 by 3.8 to 4.7 μ. Average, 40.0 by 4.2 μ.

Parallel cultures of *F. vasinfectum*, strain 1855, from cotton and strain 3592 from okra were prepared upon cotton stems as a medium. At the age of 45 days, 50 normal triseptate conidia from a pionnotes of each culture were measured to obtain the relative sizes. The maximum, minimum, and average length and width of conidia in each culture are shown in Table II. There is a close correspondence of the measurements of conidia from the two strains, considering that these measurements were made from but one culture of each strain.

TABLE II.—*Comparative size of normal triseptate conidia of Fusarium vasinfectum from okra and cotton*

	F. vasinfectum 1855 from cotton.	*F. vasinfectum* 3592 from okra.
	μ.	μ.
Maximum length	37.4	44.2
Minimum length	27.2	27.2
Maximum width	5.1	5.1
Minimum width	3.4	3.4
Average length	37.0	35.5
Average width	4.2	4.0

Fusarium vasinfectum Atkinson.

Sporodochia and perfect pionnotes present, in mass ocherous-salmon colored, the conidia being of the Elegans type, 3- to 5 septate, sickle-shaped, constricted at the apex and pedicillate at the base (Pl. 17, L,M). Conidiophores verticillately branched. Normal triseptate conidia present up to 100 per cent, 23.8 to 46.0 by 3.4 to 5.1 μ. Four-septate conidia up to 35 per cent, 34.0 to 44.0 by 3.4 to 5.0 μ. Five-septate conidia up to 5 per cent, 34.0 to 56.0 by 3.6 to 5.0 μ. Microconidia may be present in subnormal cultures up to 100 per cent, 4.0 to 14.0 by 2.0 to 3.5 μ. in size. Chlamydospores (Pl. 17, I) ellipsoidal to round, terminal, intercalary and conidial; when unicellular measuring from 8 to 15 μ. Blue-gray sclerotia on potato cylinders. Strong lilac odor on rice and other starchy media. Vascular parasite, cause of a wilt disease of *Gossypium herbaceum*, *G. barbadense*, and *Abelmoschus esculentus*.

VERTICILLIUM ALBO-ATRUM

Verticillium albo-atrum Reinke and Berthold is classified by Engler and Prantl in the section Eu-Verticillium of the genus Verticillium of the Mucedinaceae-Hyalosporae-Verticillieae. The conidophores (Pl. 17, A–D) are verticillately branched, conidia which readily fall being formed at the tips of all the branches. The distinction between the three sections of the genus—that is, Eu-Verticillium Sacc., Oncocladium Wallr., and Gliocephalum Sacc. is not sharply drawn. In the latter the conidia are held together by slime, while in Eu-Verticillium and Oncocladium this is not the case. In the opinion of the writer, *V. albo-atrum* should more appropriately be placed in the section Gliocephalum, for this is where it naturally belongs, if its characters are determined on the substratum (Pl. 17, B, D). If examined in water mounts, rarely more than one conidium would be found on each sterigma tip (Pl. 17, C), and the fungus would erroneously be placed with the section Eu-Verticillium.

DESCRIPTION OF THE FUNGUS

The conidia are ellipsoidal (Pl. 17, A), unicellular, 4.0 to 11.0 by 1.7 to 4.2 μ, abscissed singly from the tips of verticillate-branched conidiophores. They may or may not cling to the tips of the sterigma in rounded masses. In the absence of sufficient moisture in the air, relatively dry, rounded aggregates of spores accumulate; but with more moisture present spherical drops appear on the sterigma tips by virtue of the hygroscopic slime in which the conidia are embedded (Pl. 17, B). With additional moisture the drops rupture, leaving one immature conidium clinging to the sterigma. These masses measure from 3 μ to a size where the water drop breaks. The verticillate branches of the conidiophores are 1 to 7 to a whorl or virtel, more commonly 3 to 5, and these in turn may bear secondary branches in virtels. The branches are from 13 to 38 μ long, disposed in virtels 30 to 38 μ apart along the conidiophore. Conidiophores consisting of a terminal branch and two primary virtels, are about 100 to 120 μ in length, while those bearing four primary virtels measure 250 to 300 μ. Conidiophores with 7 to 8 primary virtels are occasionally

seen in petri-dish cultures. The terminal branch is usually 1 to 3 times longer than the virtel branches and measures from 15 to 60 μ.

The mycelium is hyalin at first, becoming brownish with age. It is septate, 2 to 4 μ in diameter, but is often swollen, all gradations from slightly swollen threads to large, thick-walled, and knotted sclerotia, and chlamydospore-like cells being present (Pl. 17, G). The sclerotium is at first but swollen, closely septate mycelium, which enlarges and knots itself into a variety of forms. The measurements of sclerotia of strains 1685, 1717, 2784, and 2985, recorded in Table I, were made only from the more or less rounded aggregations. Such measurements of irregular formations varying so greatly in size are only of general significance. Certain strains of *V. albo-atrum* cultivated by the writer produce sclerotia abundantly in a few days in petri-dish cultures. Macroscopically, their presence is manifested by a beautiful black zonation of the colonies, as illustrated in Plate 19. In other strains, and sometimes in other cultures of the same strain, these sclerotial rings either do not develop at all or only after a long time; yet these forms produce abundant sclerotia if cultivated on potato cylinders and other vegetable media. The entire growth then frequently consists of a black confluent layer of sclerotia and hyphæ. Parallel cultures of the same strain differ sufficiently with respect to the characters of the conidiophores and sclerotia formation so that specific determinations based on slight differences of these characters and unsupported by inoculation tests are of doubtful value.

Verticillium albo-atrum Reinke and Berthold.

Conidia ellipsoidal, unicellular, 4.0 to 11.0 by 1.7 to 4.2 μ, abscissed singly from the sterigma tips of verticillate conidiophores. Primary whorls or virtels of branches, 1 to 8 in number, 30 to 90 μ apart, sometimes bearing secondary virtels. Branches 1 to 7, usually 3 to 5 in number, 13 to 38 μ long, tapering, straight to slightly bowed. Conidiophores 100 to 300 μ or more in length. The terminal branch of the conidiophore is from 15 to 60 μ long. Conidia may or may not collect in heads on the sterigma tips. Mycelium septate, hyalin to brown with age; may become swollen into chlamydospore-like chains of closely septate, knotted masses. These aggregates constitute the sclerotia of this fungus. Vascular parasite, cause of a wilt disease of okra, potato, eggplant, cotton, snapdragon, and probably of species of Abutilon and Xanthium, ginseng, black raspberry, China aster, and dahlia. *V. albo-atrum* may prove to be the cause of the Verticillium-wilt disease reported on currants and gooseberries by Aderhold (*1*).

OCCURRENCE OF FUSARIUM VASINFECTUM AND VERTICILLIUM ALBO-ATRUM IN WILT DISEASES OF OKRA

Verticillium albo-atrum was found constantly inhabiting the vascular system of wilt-diseased okra plants (Pl. 27) in New Jersey, where this crop is of considerable importance. This organism was also isolated from similar material from Monetta, S. C., Birmingham, Ala., Middle River, Cal., and Medford, Oreg., specimens from Middle River and Medford having been collected by Dr. Wollenweber.

On the other hand, a Fusarium indistinguishable from the cotton-wilt Fusarium was constantly obtained from wilting okra collected at

Florence, Sumter, and Charleston, S. C., and Wrightsboro, N. C. According to Clinton (*8*), the Fusarium-wilt of okra occurs in Connecticut. *Fusarium vasinfectum* was not obtained by the writer from okra-wilt in New Jersey; and *Verticillium albo-atrum* was isolated from this host in the South only in the few mentioned localities.

V. albo-atrum was isolated from a wilt disease of the weeds *Abutilon* sp. and *Xanthium* sp. in New Jersey; and from spontaneous wilt of cotton plants in rows adjoining the experimental plot at Arlington, Va.

The wilt diseases of the several plants brought about by *F. vasinfectum* and *V. albo-atrum* manifest the same symptoms, so that the real cause of the trouble is safely to be determined only by cultural means. There is a lack of turgor in the leaves first in evidence in those parts farthest removed from the veins (Pl. 20–23). The lower leaves are first affected, wilt, and drop off one or two at a time. Frequently the plant does not die for a long time, but continues a dwarfed existence. This is especially true of the Verticillium-wilt. If the plants are cut longitudinally and crosswise, it will be seen that the vascular tissue is brown or black (Pl. 18), the discloration being traceable from the small roots to the top of the stem and into the petioles. Microscopic examination of thin sections of this material shows that the vessels are plugged with the mycelium of the parasite, which interferes with the conduction of moisture to the aerial portions of the plant (Pl. 17, E). The host tissues do not appear to be invaded or broken down, the vascular inhabitant merely living as a saprophyte on the fluids of the vessels, and injuring the host plant only by mechanical obstruction of the latter. Whether there are injurious products secreted in the metabolism of the fungus detrimental to the plant in other ways is yet to be demonstrated. The parasitism of these fungi is, then, a mechanical interference with the nutrition of the host and not our usual conception of this term.

METHOD OF TESTING PARASITISM

In order to demonstrate the ability of *V. albo-atrum* and *F. vasinfectum* to produce wilt diseases of okra and to gain a knowledge of the relation of these organisms to other host plants, approximately 1,000 inoculations[1] and cross-inoculations with pure cultures were made. Strains of *V. albo-atrum*, isolated from okra, eggplant, potato, and snapdragon, were used to inoculate okra; strains from okra, snapdragon, and eggplant were used to inoculate eggplant; and the strain from okra was used to inoculate cotton. Similarly okra plants were inoculated with *F. vasinfectum* isolated from okra and cotton; and cotton was inoculated with this fungus isolated from cotton and okra.

The general method used in the inoculations may be summarized as follows: Selected okra seed, or seed of other plants to be used, were disinfected in a solution of formalin, rinsed in sterile water, and planted in

[1] The writer is indebted to Mr. J. M. R. Adams for faithful assistance in the inoculation tests.

sterilized soil in the greenhouse, or in soil new to these crops in field plots. Soil inoculations were made by pouring a few cubic centimeters of a sterile-water spore suspension of the organism to be used on the steam-sterilized soil, either before or after planting the seed, or in the vicinity of the seedlings. The majority of the inoculations were made through wounds at the hypocotyl below the soil level. The wounds were made with a sterile scalpel, and after the inoculum was introduced, the soil was replaced to prevent drying. A few inoculations were made through wounds made by breaking off leaves and pods of the okra plants.

Approximately as many control plants were prepared as plants for inoculation. Half of these were wounded or otherwise subjected to the treatment employed on the plants inoculated, and the other half were left as unwounded controls. For the wounded controls, sterile water was used for inoculating, in lieu of the spore suspension. Wilting plants were examined microscopically for mycelium in the xylem of roots, stem, or petioles; and pure cultures of the organism used were reisolated and identified as a control on the work. Frequently such reisolated strains were used for subsequent inoculations.

In but one experiment was there any wilt in the controls. In this case after six weeks 6 per cent wilted, and the organism used in the experiment was recovered from the interior of the plants. However, this was a field test and there was in the duration of the experiment an opportunity for infection from inoculated plants in the adjoining rows on either side.

INOCULATION OF VARIOUS ECONOMIC PLANTS WITH VERTICILLIUM ALBO-ATRUM AND FUSARIUM VASINFECTUM

Inasmuch as the inoculation experiments were carried on in a uniform manner and controlled by a large number of wounded and unwounded plants, as well as by reisolation and identification of the organisms causing the disease, the results are comparable. For convenience these results are brought together in tabular form (Tables III, IV, V) and the discussion of the results of the inoculations are arranged according to the host plant and the parasite used.

HISTORY OF THE STRAINS OF VERTICILLIUM ALBO-ATRUM AND FUSARIUM VASINFECTUM USED FOR INOCULATION

The history of the various strains of *V. albo-atrum* and *F. vasinfectum* used for inoculating the several host plants is as follows:

F. vasinfectum strain 1855. Reisolated from the vascular system of a cotton plant, which was wilting as a result of inoculation with strain 1733, a reisolation of strain 1635, which was in turn a reisolation of the original strain 1485, isolated from the discolored vascular system of a wilting cotton plant at Florence, S. C., in 1912.

F. vasinfectum strains 2708, 2709, 3203. Isolated from the discolored vascular system of wilting okra plants collected at Florence, S. C. at

different times. Strain 3592 is a reisolation from an okra plant inoculated with strain 3203.

F. vasinfectum strain 3210. Isolated from the vascular system of an okra plant collected at Sumter, S. C.

V. albo-atrum strain 1717. Isolated from the interior of the stem of a wilting okra plant at Monetta, S. C. Strains 2943, 3075, 3076, and 3156 are reisolations from okra plants inoculated with strain 1717.

V. albo-atrum strain 2821. Isolated from wilting okra plant collected at Middle River, Cal.

V. albo-atrum strain 1685. Isolated from wilting plant of *Solanum melongena*.

V. albo-atrum strain 2784. Isolated from wilting potato plant.

V. albo-atrum strain 2985. Isolated from wilting snapdragon plant by Brown (*4*).

TABLE III.—*Results of inoculating okra plants with Verticillium albo-atrum from various hosts*

Number of plants	Age.	Locality.	Method of inoculation.	Species and strain of organism.	Incubation period.	Percentage ultimately wilting.	Time.
	Days.				*Days.*		*Days.*
40	17	Greenhouse.	Soil.....	*V. albo-atrum*, okra (1717).	12	88	21
60	(a)	.....do.....	.....do.....	.....do.....	40	59	60
60	(a)	.....do.....	.....do.....	*V. albo-atrum*, Irish potato (2784).	40	55	60
40	37	.....do.....	Wounds: hypocotyl.	*V. albo-atrum*, okra (1717).	11	100	30
16	46	.....do.....	.....do.....	.....do.....	13	81	30
12	90	.....do.....	.....do.....	.....do.....	18	100	30
13	30	.....do.....	.....do.....	.....do.....	12	92	30
17	46	.....do.....	.....do.....	*V. albo-atrum*, okra (3075).	15	66	30
17	46	.....do.....	.....do.....	*V. albo-atrum*, okra (3076).	13	17	30
40	46	.....do.....	.....do.....	*V. albo-atrum*, okra (2943).	13	40	30
9	90	.....do.....	.....do.....	*V. albo-atrum*, okra (2821).	18	100	24
40	46	.....do.....	.....do.....	*V. albo-atrum*, snapdragon (2985).	.....	0	30
40	46	.....do.....	Wounds: pedicel.	*V. albo-atrum*, okra (1717).	.....	0	30
26	30	.....do.....	.....do.....	.....do.....	.....	0	45
58	60	Field.....	Wounds: hypocotyl.	.....do.....	10	75	43
14	60	.....do.....	.....do.....	*V. albo-atrum*, okra (3156).	14	71	23
19	60	.....do.....	.....do.....	*V. albo-atrum*, eggplant (1685).	10	36	43
26	60	.....do.....	.....do.....	*V. albo-atrum*, Irish potato (2784).	10	73	43
22	60	.....do.....	.....do.....	*V. albo-atrum*, snapdragon (2985).	10	45	43

[a] Soil inoculated before planting the seed.

TABLE IV.—*Results of inoculating okra plants with Fusarium vasinfectum from cotton and okra*

Number of plants	Age.	Locality.	Method of inoculation.	Species and strain of organism.	Incubation period.	Percentage ultimately wilting.	Time.
	Days.				*Days.*		*Days.*
40	17	Greenhouse.	Soil.....	*F. vasinfectum*, okra (2709).	.....	0	56
40	17	.....do.....	.....do.....	*F. vasinfectum*, cotton (1855).	.....	0	56
40	37	.....do.....	Wounds: hypocotyl.	.....do.....	.....	0	56
99	21	.....do.....	.....do.....	.....do.....	17	1	36
40	37	.....do.....	.....do.....	*F. vasinfectum;* okra (2709).	.....	0	56
40	37	.....do.....	.....do.....	*F. vasinfectum*, okra (2708).	.....	0	56
30	24	.....do.....	.....do.....	*F. vasinfectum*, okra (3203).	5	50	15
50	49	.....do.....	.....do.....	.....do.....	.....	0	30
100	10	.....do.....	.....do.....	.....do.....	6	55	18
20	60	.....do.....	.....do.....	*F. vasinfectum*, okra (3210).	.....	0	23
17	21	.....do.....	.....do.....	*F. vasinfectum*, okra (3592).	17	6	36

TABLE V.—*Results of inoculating cotton, eggplant, and Brabham cowpeas with the okra-wilt organisms through wounds at the hypocotyl*

Host.	Number of plants.	Age.	Locality.	Species and strain of organism.	Incubation period.	Percentage ultimately wilting.	Time.
		Days.			*Days.*		*Days.*
Cotton.....	14	60	Field.....	*F. vasinfectum*, okra (3210).	.....	0	23
Do.....	20	60	.....do.....	*V. albo-atrum*, okra (3156).	14	80	23
Do.....	18	21	Greenhouse..	*F. vasinfectum*, cotton (1855).	17	89	36
Do.....	43	21	.....do.....	*F. vasinfectum*, okra (3592).	17	87	36
Eggplant.....	7	45	.....do.....	*V. albo-atrum*, okra (1717).	10	85	15
Do.....	5	45	.....do.....	*V. albo-atrum*, snapdragon (2985).	10	80	15
Do.....	7	45	.....do.....	*V. albo-atrum*, eggplant (1685).	10	100	15
Brabham cowpeas.	16	24	.....do.....	*F. vasinfectum*, okra (3203).	.....	0	60

INOCULATION OF OKRA

No difficulty was experienced in securing typical wilting okra plants (Pl. 21, 22) by the inoculation of the soil or of the plants through wounds at the hypocotyl with pure cultures of *V. albo-atrum* isolated from okra, eggplant, potato, or snapdragon. By the inoculation of the soil in the vicinity of 17-day-old plants with strain 1717 isolated from okra, 88 per cent of wilting plants were obtained in 21 days. Inoculations of the soil with this strain before planting the seed resulted in 59 per cent of wilt. Inoculation of 37- to 90-day-old okra plants with this strain through the hypocotyl gave from 75 to 100 per cent of wilting plants. The reisolated strains of *V. albo-atrum* 1717 gave the following results: Strain 2943, 40 per cent; strain 3075, 66 per cent; strain 3076, 16 per cent; strain 3156, 71 per cent. *V. albo-atrum*, strain 2821, isolated from a wilting okra plant from Middle River, Cal., produced 100 per cent of wilting plants through hypocotyl inoculations.

The introduction of *V. albo-atrum* into wounds of the pedicel and the stem of okra plants was without apparent effect, thus indicating that there is no danger of carrying the wilt disease from plant to plant by the cutting knife.

The inoculation of okra plants with *V albo-atrum* from hosts other than okra gave the following results: Strain 2985, isolated from snapdragon, produced from none to 45 per cent of wilt through hypocotyl inoculation; strain 2784 from potato gave 73 per cent through hypocotyl wounds and 55 per cent through soil inoculation previous to planting the seed; strain 1685, isolated from eggplant, gave 43 per cent of wilt through the inoculation of 60-day-old plants at the hypocotyl.

The results of inoculating okra plants with *F. vasinfectum* were for some time disappointing. However, after an insight was gained into the conditions necessary to induce the Fusarium-wilt of okra, better results were obtained. With the species of Fusarium from okra in two trials, 50 and 55 per cent of wilting plants were secured by inoculation through the hypocotyl (Pl. 23). But with the species of Fusarium from cotton only 1 per cent was obtained. However, the cotton inoculated with the species of Fusarium (3592) from okra and the strain (1855) from cotton gave a high percentage of wilting plants in a parallel test of the two strains (Pl. 24–26).

INOCULATION OF COTTON

Fusarium vasinfectum strain 1855 from cotton, when introduced into wounds at the hypocotyl of 21-day-old plants, gave 50 per cent of wilt in 17 days and a total of 89 per cent in 5 weeks (Pl. 25). Similarly, in a parallel test, *F. vasinfectum* strain 3592 from okra gave 42 per cent of wilt in 17 days and a total of 87 per cent in 5 weeks (Pl. 26). In contrast to these results are those secured with these strains on okra in the parallel

test where but 1 and 6 per cent of wilt was secured. *Verticillium albo-atrum* strain 3156 inoculated through wounds of the hypocotyl gave 80 per cent of wilt in 14 days.

The Verticillium-wilt of cotton, as observed in these tests can not be distinguished from the very destructive Fusarium-wilt of this crop unless a critical examination be made. It is possible that this wilt is present in the cotton fields of the South and has been overlooked, owing to the similarity of the two diseases.

INOCULATION OF EGGPLANT

Eggplant was found to be susceptable to the strains of *V. albo-atrum* isolated from okra, eggplant (Pl. 20), and snapdragon. Strain 1717 from okra gave 85 per cent of wilt in 15 days; strain 1685 from eggplant gave 100 per cent in the same time, and strain 2985 from snapdragon 80 per cent correspondingly. The inoculations were made through wounds of the hypocotyl on 45-day-old plants.

INOCULATION OF BRABHAM COWPEAS

Twenty-four-day-old seedlings of Brabham cowpeas were inoculated through the hypocotyl with *F. vasinfectum* strain 3203 from okra. Although held under observation for 60 days, no cases of wilt were detected.

CONCLUSIONS

There are two similar wilt diseases of okra, caused, respectively, by *Fusarium vasinfectum* and *Verticillium albo-atrum*. These diseases can be differentiated only by isolating the causal fungi. The Fusarium-wilt in general is more serious in the southern range of okra growing, while the Verticillium-wilt is more serious in the northern range of this crop. However, the former has been reported in Connecticut, and the latter occurs in South Carolina and Alabama.

The wilt diseases of the Irish potato offer a parallel case of two organisms producing the same disease symptoms. Here, the Fusarium-wilt is induced by *F. oxysporum* and the Verticillium-wilt by *V. albo-atrum*, as in okra. Similarly, it is demonstrated in this paper for the first time that cotton may have both wilt diseases. No doubt there are several other economic plants, which act as host to vascular parasites of the genera Fusarium and Verticillium—for example, China aster, ginseng, eggplant, brambles.

V. albo-atrum was isolated from the discolored vascular system of wilting plants of okra, eggplant, potato, and species of Abutilon and Xanthium, and was demonstrated in these studies to be the cause of a wilt disease at least of okra, eggplant, and cotton. It was identified from a wilt disease of snapdragon after its causal relation to this disease had been established by Miss Nellie A. Brown, of the Bureau of Plant

Industry. Okra is susceptible to inoculation with *V. albo-artum* from okra, snapdragon, eggplant, and potato; and to *F. vasinfectum* from okra. Eggplant is susceptible to *V. albo-atrum* from eggplant, okra, and snapdragon. Cotton is susceptible to the strains of this fungus from okra and to *F. vasinfectum* from okra and cotton.

Thus, it is apparent that the species of Fusarium causing the wilt disease of okra is identical with *F. vasinfectum*. Likewise it is evident that *V. albo-atrum* is a serious vascular parasite of a number of different economic plants. In view of the fact that the genus Acrostalagmus should be combined with the earlier genus Verticillium, it seems probable that *V. albo-atrum* is the fungus described by Van Hook under the name "*Acrostalagmus albus*," the cause of ginseng-wilt; by Lawrence as *A. caulophagus*, the cause of the bluestem disease of black raspberry; and by Gueguen as *A. vilmorinii*, the cause of a wilt disease of China aster and associated with a disease of cacao fruits.

V. albo-atrum and *F. vasinfectum* are readily cultivated artificially, indicating that both are capable of persisting saprophytically in the soil for an indefinite period in the absence of the preferred host. There was no indication that either fungus is carried from field to field or from year to year by the seed or from plant to plant by the cutting knives.

As a control measure it may be suggested that seed be selected only from healthy plants. If extreme precaution is to be taken, the seed may be disinfected in a formalin solution (1 to 240) for two hours.

Since okra, eggplant, potato, cotton, snapdragon, and the weeds *Xanthium* spp. and *Abutilon* spp. are all susceptible to the Verticillium-wilt, as well as ginseng, China aster, and black raspberry, as seems probable, these plants should be taken into consideration in planning a rotation to eliminate wilt diseases. Similarly, okra and cotton are hosts of *F. vasinfectum* and should not follow each other in rotation if best results are expected.

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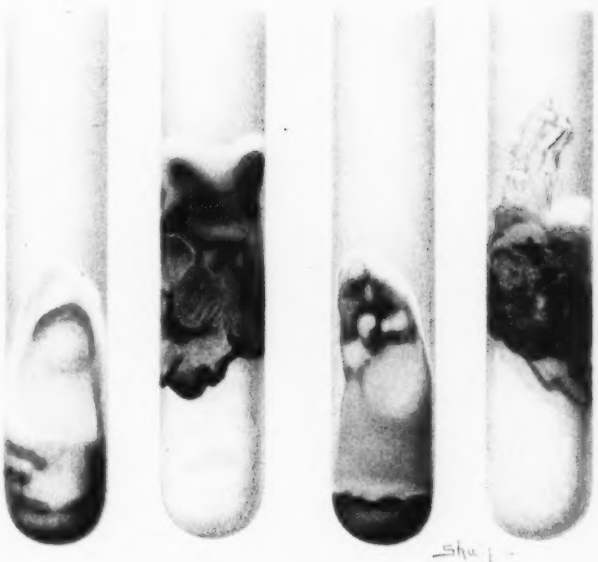
PLATE A

Fusarium vasinfectum on vegetable media:

1–3.—Growth on steamed potato. Both potato cultures show pionnotes.
2, 4.—Growth on rice.
Cultures 1 and 2 were grown in a strong north light; 3 and 4 in a subdued light.



1 2 3 4

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PLATE 17

A–H.—*Verticillium albo-atrum:*

A, Simple conidiophores and conidia. ×1,000.

B, Same showing, respectively, the collection of the conidia on the sterigma in irregular aggregations in dry air, and in water drops in humid air. ×1,000.

C, Verticillate conidiophores bearing one and three whorls, or virtels, of branches, respectively. ×500.

D, Verticillate conidiophore having conidial heads, from humid environment—that is, moisture drops in which the conidia float as in figure B. This is the so-called Acrostalagmus type of conidial head. ×500.

E, Mycelium of *V. albo-atrum* in the vascular ducts of an okra plant inoculated with this fungus. ×250.

F, H, Germinating conidia: F, ×500; H, ×1,000.

G, Swollen, sclerotia-like mycelium. ×500.

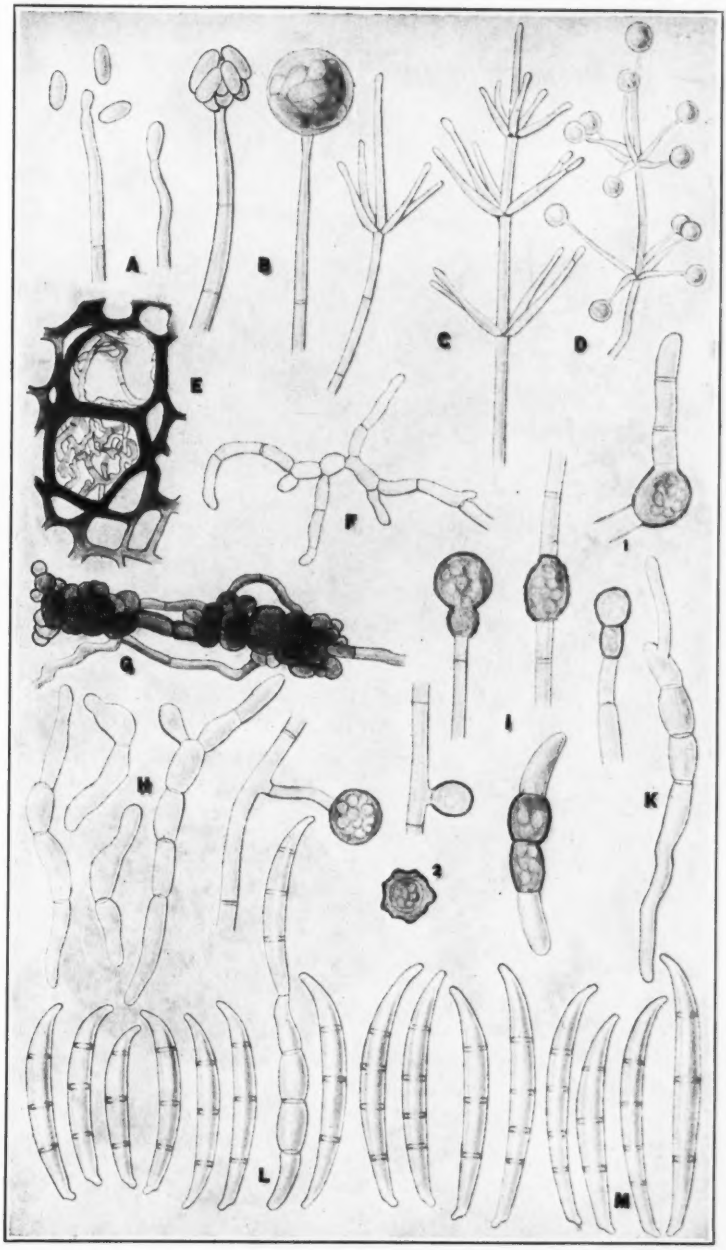
I–M.—*Fusarium vasinfectum:*

I, Terminal, intercalary and conidial chlamydospores. 1, Germinating terminal chlamydospore. 2, Free mature chlamydospore. ×1,000.

K, Germinating macroconidium. ×1,000.

L, *F. vasinfectum* from okra-wilt. Twelve macroconidia. ×1,000.

M, *F. vasinfectum* from cotton-wilt. Four macroconidia. ×1,000.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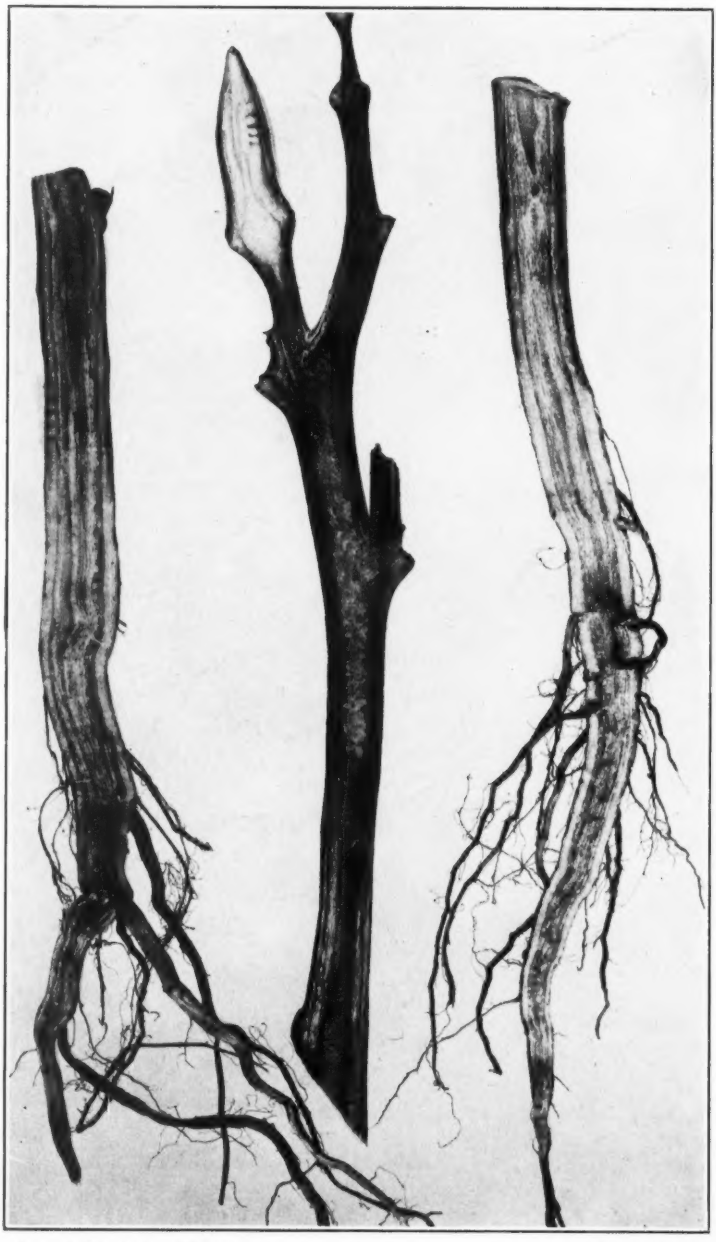


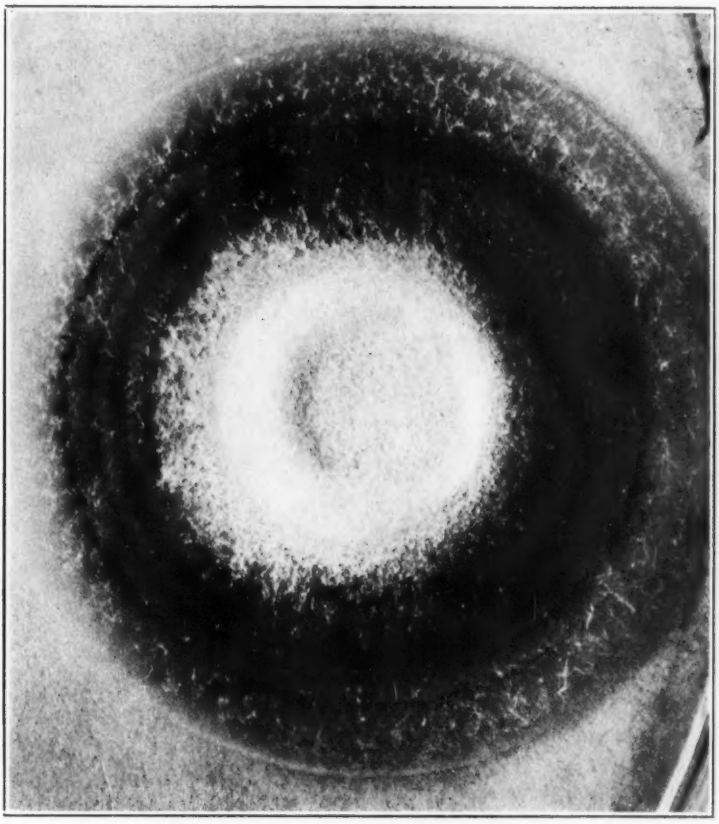
PLATE 18

Longitudinal section of an okra plant naturally infected with *Verticillium albo-atrum*, showing the typical appearance. The vascular elements are discolored from the roots to the pedicels and petioles. About natural size.

PLATE 19

Verticillium albo-atrum:

Two-weeks-old colony on potato agar, showing the concentric rings of black sclerotial bodies. ×4.



B
A

PLATE 20

Solanum melongena, showing effect of wilt:

A.—Control plant of the same age as the wilted plant (B). Photographed at the same time as figure B. ×2/5.

B.—Wilted plant photographed two months after inoculation at the hypocotyl with *Verticillium albo-atrum* isolated from wilted eggplant. The organism was recovered from the stem of the small plant 10 cm. above the point of inoculation. ×2/5.

PLATE 21

Abelmoschus esculentus, showing effect of wilt:

A.—Control plant. Photographed at the same time as figure B. × (about) 1/2.
B.—Wilted plant photographed two weeks after inoculation at the hypocotyl with a pure culture of *Verticillium albo-atrum*. × (about) 1/2.

B
A

A
B

PLATE 22

Abelmoschus esculentus, showing effect of wilt:

A.—Wilted plant inoculated with *Verticilium albo-atrum*. × (about) 1/3.
B.—Control plant of the same age as wilted plant. × (about) 1/3.
Both plants were photographed two months after the wilted plant had been inoculated.

PLATE 23

Abelmoschus esculentus, showing the effect of wilt as a result of inoculation with *Fusarium vasinfectum* isolated from okra-wilt. The inoculation was made at the hypocotyl and the organism was recovered from the vascular tissues of the petioles two weeks afterwards—that is, immediately after the photograph was taken. ×2/3.

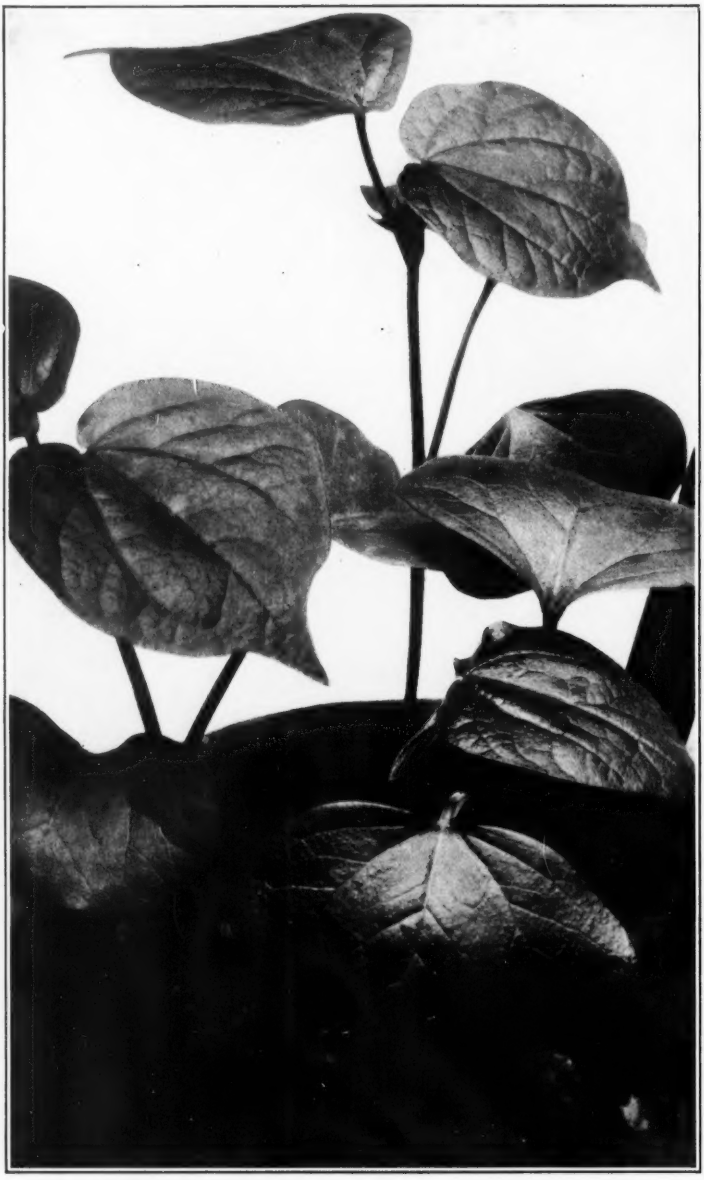


PLATE 24

Gossypium herbaceum (Columbia variety):

Control plants 35 days old. Photographed 15 days after having been wounded at the hypocotyl. Natural size.

PLATE 25

Gossypium herbaceum (Columbia variety), showing effect of wilt:

Wilting plants photographed 15 days after inoculation at the hypocotyl with *Fusarium vasinfectum*, strain 1855, isolated from wilting cotton plants. The plants are the same age as the control plants in Plate 24. Natural size.

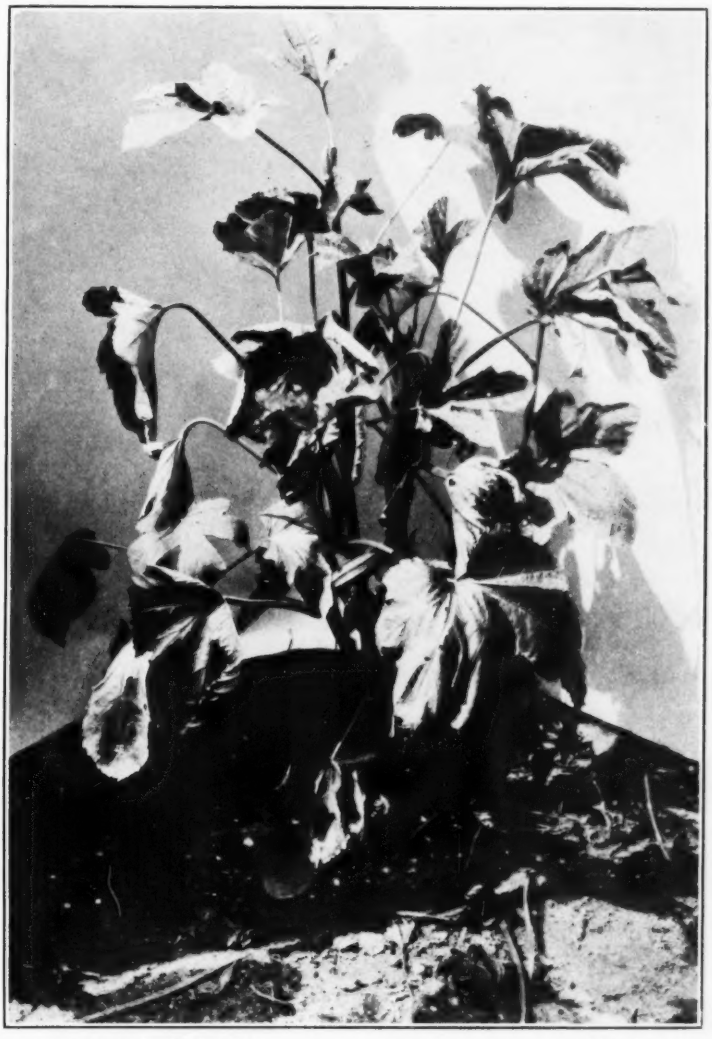
PLATE 26

Gossypium herbaceum (Columbia variety), showing effect of wilt:

Wilting plants photographed 15 days after inoculation at the hypocotyl with *Fusarium vasinfectum*, strain 3592, isolated from wilting okra. The plants are the same age as those in Plates 24 and 25. Natural size.

PLATE 27

Abelmoschus esculentus, showing the characteristic symptoms of the wilt produced by *Verticillium albo-atrum*. Photographed in a field in New Jersey.



WINTER CYCLE OF EGG PRODUCTION IN THE RHODE ISLAND RED BREED OF THE DOMESTIC FOWL

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INTRODUCTION

The winter cycle of egg production is one of the internal factors concerned in determining total production. It was first recognized by Pearl and Surface in Barred Plymouth Rocks. They state (*7, p. 99–100*):[1]

> It will undeniably be advantageous, in studying certain phases of the problem of egg production, to endeavor to use a time unit which conforms to the *natural periodicity* displayed by hens [italics are mine—H. D. G.]. . . .
>
> The plan followed at the present time in the investigations in progress at the Maine Station breaks the laying year up into four parts. The first of these includes the months of November, December, January, and February. Broadly speaking, this is the period of winter laying and is so designated. . . .
>
> The justification for the conclusion that this division of the year is in general a natural one and corresponds to a real cyclical periodicity in egg production is in considerable measure to be found in the facts regarding mean monthly egg production and variation in this character set forth in this and the preceding section of the paper. The winter-laying period is a period characterized by rapid increase in mean production associated with a relatively equally rapid decrease in variability, both absolute and relative. In this period a large part of the flock falls in the A component of the monthly distributions (see p. 142). This laying period is, strictly speaking, not a part of the natural or normal reproductive cycle of the hen. Egg laying in this part of the year is something which during domestication has been added on, as it were, to the natural reproductive activity of the wild *Gallus*. It is a result of "forcing" or special stimulation. From the evolution standpoint, egg production in these months is a comparatively recent acquisition. Such being the case, the greater variability observed in winter laying is only what would be expected.
>
> The limits of this artificial winter cycle of egg production are fairly well defined. It begins with the beginning of the laying year. Its other limit is marked by the slacking up in egg production, which occurs in February (see Fig. 1). This slackening up in February, which appears to be a characteristic of egg production, generally, is to be explained, we believe, chiefly if not entirely as the result of the ending of the winter cycle by the majority of birds which have laid during the early winter. Such birds rest for a period at about this time before beginning the spring laying cycle. Of course it must be understood that these statements are made only with reference to what might be called the general or average course of events. Particular birds may form exceptions in their laying. Many birds, of course, have no proper winter cycle of laying at all. They begin to lay for the first time in January or February, and keep on laying without any large break straight through the spring cycle.

[1] Reference is made by number (italic) to "Literature cited," p. 574.

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In discussing the monthly egg distribution Pearl and Surface (*7, p. 89–90*) state:

> Considering the form of the polygon somewhat more in detail, we note that the line starts from a low point in November and rises rather rapidly and in almost a straight line to January. The slope of the line from January to February is downward. In other words, there is an indentation in the ascending limb of the egg-production polygon in the month of February. This is a very characteristic feature of the distribution of egg production, not only observed with the birds here under discussion but also in published records from other sources.
>
> A study of Table 1 shows that this is generally true for every year covered by the investigation. While the February mean production is not necessarily lower than the January, though this is true in many cases, there is a perceptible slowing of the rate of increase in egg production which has obtained up to that time. The most probable interpretation of this appears to us to be that the February indentation in the egg-production curve represents a rest or reaction after the winter laying and in anticipation of the heavy March and April production. It marks the completion of a laying cycle on the part of those birds which have been laying during the winter months.

The mean egg production for February, however, seems to rest on a basis of 28 days. If reduced to a basis of 31 days, the mean production is 12.03 eggs, a value, however, that produces a pronounced indentation in the upward slope of the polygon. Pearl believes that this change in the slope of the polygon, disregarding entirely any actual drop in production, is indicative of a winter cycle. However, a change in the slope of such a polygon would occur if a flock of birds began to lay in some given month, gradually increased in production for a definite period of some length until they reached a maixmum and maintained this maximum for a period of several months. Pearl, moreover, is inclined to believe that the change in mean temperature that occurs in March bears no causal relation to the increase in egg production that is observed at this season. Now, while it is clear that there are other factors than the change in temperature that increases production at this season, it is not at all clear that temperature can be entirely eliminated as a factor. In the imaginary case just mentioned it seems possible that the maximum production under one set of environmental conditions might be different from that observed under another set. Hence, it seems entirely probable that the maximum production possible in January and February would not be as high as in March, and that the indentation noted in the curve of production merely means that the maximum production possible for midwinter conditions has been reached.

In several other papers, notably those of Pearl (*5, 6*), the winter cycle is again discussed. In the former paper he states (*5, p. 173–174*):

> (2) The upper limit of the winter period at March 1 is arbitrary, and only approximately coincides with the biological reality. Actually with most birds the spring or reproductive cycle of production (cf. 37) begins in the latter part of February. In handling the material it has been found necessary (for reasons which will be

obvious upon consideration of the matter) to take a fixed date for the beginning of the spring cycle of laying and the ending of the winter cycle. The records of the station prior to 1908 are tabulated only for months (the daily records unfortunately having been destroyed before I took charge of the work), and on this account it is necessary to take the working limit of the winter cycle at the end of a calendar month. Since March 1 comes the nearest to the biological limit of any date which is also the beginning of a calendar month it has been chosen. The error introduced by taking this arbitrary date for a point which really shifts within rather narrow limits is, on the average, small. However, it must be recognized as a disturbing element in the individual case. Thus, some birds which really lack any genetic factor for winter production will begin to lay in the last days of February, and consequently on the arbitrary "March 1" basis will actually be credited with a small winter production. This will tend to make the number of zero birds observed smaller than that expected on theory.

In the latter paper, entitled "Measurement of the Winter Cycle in the Egg Production of Domestic Fowl," a comparison is made between the egg production of a pullet during the first 300 days of its life with its egg production up to March 1 of the pullet year. He finds that there is very little difference in the value of these two measures of production

The evidence for a winter cycle published by Pearl is all mass evidence. The possibility that a flock might be heterogeneous in respect to the winter cycle is not considered by him. It is true that he speaks of particular birds forming exceptions to the rule in their laying, but the sentence immediately following seems to indicate that Pearl has in mind birds that begin to lay late in the winter (*7, p. 100*) rather than birds that lay throughout the winter. However, a few records that form real exceptions to the rule can be found in the records of individual Barred Plymouth Rocks published by Gowell (*3, 4*).

Pearl's mass evidence of the existence of a winter cycle is supported by a study of the records described below. While a cursory examination of the data on egg production of Rhode Island Reds at this Station indicates that a considerable percentage of our records are without visible indications of a winter cycle (since many birds that begin to lay in November continue to lay without noticeable slackening of production straight through the winter and spring), at the same time there are many instances in which the existence of a winter cycle is indisputable. Records of both sorts may also be observed in the reports from various egg-laying contests. Further, an examination of Gowell's records of the monthly egg production of individuals (*3, 4*) shows in most instances a marked decrease in the production for February over January, indicating that the birds either stop laying entirely for a time during one or both months or that they slow down in their daily rate. The former alternative, in view of Pearl's statements, appears to represent the facts. A few records published by Miss Curtiss in another connection also show the same thing.

Since inspection of our records shows the possibility of the existence of two types of birds with respect to a winter cycle—namely (1) those exhibiting such a cycle, and (2) those that lay but give no evidence of a cycle—it becomes necessary to examine the matter in detail, and especially to endeavor to discover some criterion by which any individual may be suitably classified. This has been attempted by a study of individual records associated with a study of the length and seasonal distribution of pauses in production as well as a study of the monthly rate of production.

MATERIAL AND METHODS

The material studied consisted of the daily egg records of three flocks of Rhode Island Red pullets, hatched, respectively, in 1913, 1915, and 1916. While Pearl has never published individual records bearing on this point, Gowell, who initiated the work at the Maine Station, has published the individual monthly egg records of the flocks making their pullet records in 1899–1900, 1900–1901, 1901–2 (*3*, *4*). These have been used for comparison with our records. Further comparisons are outside the scope of this paper.

It is obvious that a cycle in production should appear on the record in one of two ways. Either there is a period of continuous egg production followed by a period in which no eggs whatsoever are laid, or else the period of production is followed by a period in which eggs are produced at a less rapid rate than previously. It is well known to poultrymen that hens often lay well for a while and then enter on a resting period of variable length. The egg-producing period may be designated as a "litter." This is, of course, one form of cycle, but is to be distinguished in most cases from the winter cycle through the fact that the period of egg production is in the latter relatively long and may be composed of more than one litter. As a rule the only difficulty encountered is the case where a single litter extends over the entire winter. In this instance one can not tell whether one has a winter cycle, or a very long litter, or whether the two coincide.

Since any cycle consists of a productive phase and a nonproductive phase, we have put the original records into tabular form (Table I), to which the reader's attention is directed in lieu of a detailed account of individual histories and variations. In studying this table we have come to pay particular attention to the pauses in production, since these serve as our visible indexes of cycles.

EXPLANATION OF TABLE I

In Table I the details of the records of several families are shown. Practically all the different sorts of pauses are illustrated. Pauses of less than three days in length have not been included. The arrangement of the tables by families brings out the strong resemblances between the members of the various families. The record of the mother is printed in italics at the head of the list of her daughters.

Daughters that became broody before March 1 are given in bold-faced type. Among other things listed in the column headed "Remarks," pauses occurring after March 1 and extending through April 30 are listed and are to be read as follows: The date of the beginning of a pause is given, followed by its length, and in case more pauses occur it is indicated by the number of eggs (inclosed in parentheses) followed by the length of the succeeding pause. Thus, No. 9277 in the family of male 3617 by female 6003, a pause of 7 days length began April 7, when the bird laid one egg followed by a 3-day pause.

Families sired by male 3617.—The progeny of one father and two mothers. None of the members of these families shows a well-defined winter cycle. The February egg production, in most cases where production began January 1 or before, is greater than for January. The families are also noteworthy because of the number of birds without any pause exceeding two days in length.

Family sired by male 5240.—In this family several individuals have a well-defined winter cycle; others lack such a cycle.

Family sired by male 4786.—This family is characterized by the existence of a single short pause in each record.

Family sired by male 6781.—This family is characterized by numerous pauses of varying lengths.

Family sired by male 4723.—This is a heterogeneous family.

TABLE I.—*Details of the winter egg production of several families of Rhode Island Reds*

TWO FAMILIES SIRED BY MALE 3617

Band No.	Date hatched.	Date of first egg.	Number of eggs to Mar. 1.	Number of pauses.	Total length of time spent in pauses.	Length of each pause.	Date of first and last day of each pause.	Number of eggs between pauses.	Number of eggs before the first pause.	Average length of pauses.	Average number of eggs between pauses.	February production greater or less than January.	Egg production.				Remarks.
													December.	January.	February and first 3 days of March.	Remainder of March.	
	1915.				Days.	Days.				Days.							
6003	*Apr. 25*	*Dec. 6*	*55*	*0*								=	*16*	*20*	*20*	*18*	
	1916.																
8748	May 7	Nov. 30	56	1	3	3	Jan. 1–3		22			=	21	18	18	18	
8749	...do.....	Nov. 24	60	2	7	3 4	Feb. 9–11..... Feb. 24–27.....	7	52	3.5		− 6	22	20	14	18	
9024	May 14	Dec. 31	41	0								+ 3	1	20	23	21	Apr. 27–3.
9276	May 21	Dec. 22	39	0								+ 3	6	16	19	16	Mar. 23–4.
9021	May 14	Nov. 27	71	0								+ 3	23	21	24	20	
9023	...do.....	Dec. 7	59	0								− 1	18	22	21	27	
9277	May 21	Jan. 20	27	0								+15	0	7	22	4	Apr. 7–7(1)3.
9279	...do.....	Feb. 28	1	0								+ 2	0	0	2	18	
9439	May 28	Jan. 19	23	0								+11	0	7	18	18	
9441	...do.....	Jan. 23	25	0								+18	0	5	23	6	Mar. 7–20.
	1915.																
4716	*Mar. 14*	*Nov. 22*	*75*	*0*								+ 1	*21*	*24*	*25*	*13*	*Mar. 15–10.*
	1916.																
8403	Apr. 23	Dec. 3	59	1	3	3	Dec. 4–6.....		1			− 1	17	23	22	16	Mar. 4–3.
8404	...do.....	Nov. 5	97	0								− 5	25	29	24	14	
8508	Apr. 30	Nov. 1	70	8	27	4 3 4 3 3 4 3 3	Nov. 16–19..... Nov. 26–28..... Dec. 7–10..... Dec. 14–16..... Dec. 18–20..... Jan. 7–10..... Jan. 17–19..... Feb. 4–6.....	5 5 3 1 11 4 11	12	3.4	5.7	+ 9	15	15	24	22	Mar. 20–3.
8509	...do.....	Dec. 1	61	0								+ 1	22	20	21	21	
9039	May 14	Jan. 1	36	0								+ 1	0	19	20	20	Apr. 27, inc.
9041	...do.....	Nov. 25	77	0								+ 1	26	24	25	25	
9042	...do.....	Jan. 10	32	0								+ 6	0	14	20	12	
9444	May 28	Jan. 5	37	0								+ 3	0	18	21	23	
9446	...do.....	Dec. 13	58	1	3	3	Dec. 25–27.....		9			+ 1	12	24	25	17	
8740	**May 7**	**Dec. 2**	**55**	**1**	**28**	**28**	**Feb. 6–Mar. 5**.....		**55**			**−21**	**24**	**26**	**5**	**23**	

FAMILY SIRED BY MALE 5240

6404	1915. *Mar. 9*	*Dec. 7*	*53*	*1*	*18*	*18*	*Feb. 19–Mar. 7*		*53*			− 9	*20*	*21*	*12*	*22*	*Pause due to broodiness.*
	1916.																
7625	Mar. 12	Sept. 20	110	0								+ 3	20	18	21	18	
8148	Apr. 16	Oct. 5	106	1	23	23	Jan. 25–Feb. 16		96			− 8	27	21	13	10	Mar. 8–16.
8424	Apr. 23	Oct. 6	100	3	10	4	Oct. 7–10	52	1	3.3	42	+ 1	21	21	22	17	Mar. 6–6.
						3	Dec. 18–20	32									
						3	Feb. 6–8										
8559	Apr. 30	Oct. 19	89	3	22	3	Oct. 28–30	82	6	7.3	41.5	−10	25	21	11	18	
						9	Feb. 13–21	1									
						10	Feb. 23–Mar. 4										
8560	...do....	Oct. 23	87	1	3	3	Oct. 26–28		2			+ 1	24	20	21	20	
8561	...do....	Nov. 21	38	1	40	40	Jan. 1–Feb. 9		25			+15	20	0	15	22	
8733	May 7	Nov. 5	85	0								− 4	22	24	20	20	

FAMILY SIRED BY MALE 4786

5881	1915. *Apr. 25*	*Dec. 14*	*66*	*0*								− *1*	*14*	*28*	*27*	*26*	
	1916.																
7870	Apr. 2	Nov. 3	93	0								− 2	26	24	22	20	
8121	Apr. 16	Nov. 1	95	1	4	4	Nov. 2–5		1			− 1	27	26	25	17	
8395	Apr. 23	Nov. 19	58	1	10	10	Dec. 12–21		14			=	12	20	20	23	On floor Dec. 29.
8396	...do....	Nov. 17	69	1	5	5	Dec. 12–16		16			+ 3	18	21	24	22	
9028	May 14	Dec. 8	56	1	3	3	Jan. 2–4		17			+ 2	16	20	22	20	Dec. 8 on floor.
9215	May 21	Jan. 23	25	1	4	4	Jan. 24–27		1			+21	0	3	24	22	Apr. 5–4. On floor Jan. 7–23.
8397	**Apr. 23**	**Nov. 21**	**62**	**1**	**25**	**25**	**Jan. 11–Feb. 4**		**43**			**+14**	**27**	**8**	**22**	**24**	
9029	**May 14**	**Nov. 27**	**56**	**1**	**25**	**25**	**Jan. 5–29**		**30**			**+22**	**24**	**5**	**27**	**22**	

TABLE I.—*Details of the winter egg production of several families of Rhode Island Reds*—Continued

FAMILY SIRED BY MALE 6781

Band No.	Date hatched.	Date of first egg.	Number of eggs to Mar. 1.	Number of pauses.	Total length of time spent in pauses.	Length of each pause.	Date of first and last day of each pause.	Number of eggs between pauses.	Number of eggs before the first pause.	Average length of pauses.	Average number of eggs between pauses.	February production greater or less than January.	Egg production.				Remarks.
													December.	January.	February and first 3 days of March.	Remainder of March.	
					Days.	*Days.*				*Days.*							
	1915					5	*Jan. 10–14*	2									
						13	*Jan. 19–31*	1									
5554	*Apr. 11*	*Dec. 13*	35	4	31	3	*Feb. 2–4*	12	20	7.8	5	+ 5	*14*	*8*	*13*	*18*	
						10	*Feb. 27–Mar. 7*										
	1916.																
7550	Mar. 5	Sept. 10	59	2	81	74	Nov. 23–Feb. 4	1	48	40.5	.....	+ 13	0	0	13	17	
						7	Feb. 6–12										
						20	Sept. 11–30	2									
						16	Oct. 3–18	1									
7623	Mar. 12	...do....	36	4	124	4	Oct. 20–23	32	1	31	11.7	+ 2	5	0	2	22	On floor Oct. 11.
						84	Dec. 7–Feb. 28										
						11	Dec. 29–Jan. 8	7									
						10	Jan. 22–31	1									
7730	Mar. 19	Dec. 3	28	5	41	4	Feb. 2–5	1	15	8.4	2.8	=	15	7	7	17	
						4	Feb. 7–10	2									
						12	Feb. 14–25										
						12	Nov. 4–15	1									
						19	Nov. 17–Dec. 5	1									On floor Nov. 3–16; Dec. 6–12; Jan. 24. Apr. 11–3 (9) 4 (1) inc.
8355	Apr. 23	Nov. 3	31	4	78	5	Dec. 7–11	1	1	19.5	1	+ 20	2	5	25	23	
						42	Dec. 13–Jan. 23										
						11	Oct. 31–Nov. 10	2									
						25	Nov. 15–Dec. 9	1									
						4	Dec. 11–14	5									On floor Oct. 30; Nov. 11; Dec. 10–15.
8356	...do.....	Oct. 30	41	6	51	4	Dec. 24–27	6	1	8.5	4.6	+ 4	8	14	18	19	
						4	Jan. 7–10	9									
						3	Jan. 27–29										
						22	Nov. 21–Dec. 12	6									
						3	Dec. 22–25	1									On floor Dec. 13–15. Mar. 2–5.
8359	...do.....	Oct. 25	38	4	70	22	Dec. 26–Jan. 16	8	17	17.5	5	− 1	7	8	7	18	
						23	Jan. 27–Feb. 18										
						3	Dec. 14–16	6									
8594	Apr. 30	Dec. 10	32	3	27	3	Dec. 28–30	3	3	9	4.5	+12	10	6	18	19	On floor Dec. 10.
						21	Jan. 4–24										

FAMILY SIRED BY MALE 4723

4178	1914. June 1	Jan. 20	28	0	.....	.....	.....	.....	.....	.....	.....	.....	+12	0	9	21	20	Apr. 4–5.
8069	1916. Apr. 9	Oct. 9	55	5	46	31 3 3 6 3	Dec. 7–Jan. 6..... Jan. 17–19..... Feb. 3–5..... Feb. 7–12..... Feb. 16–18.....	7 7 1 2	33	9.2	4.3	− 3	3	13	10	18	Apr. 9–3.
8222	Apr. 16	Oct. 19	25	7	93	7 3 3 53 3 3 21	Oct. 22–28..... Nov. 1–3..... Nov. 5–7..... Nov. 20–Jan. 11... Jan. 18–20..... Jan. 24–26..... Feb. 1–21.....	2 1 8 3 2 3	2	13.3	3.2	− 2	0	8	6	16	
8223	...do.....	Oct. 8	81	1	11	11	Dec. 28–Jan. 7.....	.....	52	.....	.....	+ 9	18	11	20	20	
8320	Apr. 23	Mar. 15	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	0	14	
8627	Apr. 30	Nov. 26	19	1	59	59	Dec. 27–Feb. 23...	.....	16	.....	.....	+ 5	13	0	5	20	
8630	...do.....	Dec. 4	56	3	10	4 3 3	Dec. 9–12..... Feb. 1–3..... Feb. 5–7.....	36 1	3	3.3	18.5	− 4	16	23	19	22	
8913	May 14	Nov. 24	65	0	.....	.....	.....	.....	.....	.....	.....	− 1	21	21	20	19	
8914	...do.....	Nov. 6	31	4	69	7 5 54 3	Nov. 7–13..... Nov. 18–22..... Dec. 31–Feb. 22... Feb. 27–Mar. 1....	3 24 3	1	17.3	10	+ 5	19	0	5	16	
8917	...do.....	Feb. 22	5	0	.....	.....	.....	.....	.....	.....	.....	+ 7	0	0	7	23	
9194	May 21	Dec. 8	20	1	50	50	Dec. 29–Feb. 16...	.....	13	.....	.....	+ 9	13	0	9	21	

As inspection of these records shows that there are pronounced family resemblances in the number and length of pauses among the members of each of several families, and since environmental influences have been excluded, as far as possible, it is evident that our material is not homogeneous from the biometrical standpoint. Consequently most of the usual biometrical constants have not been calculated, since in this case such constants tend to conceal the differences we are endeavoring to find.

MEANS BY WHICH A WINTER CYCLE MAY BE RECOGNIZED

A.—PAUSES

LENGTH AND SEASONAL DISTRIBUTION

Two questions arise in regard to the length of the pauses: First, is there any significant difference in the length of pauses? Second, is there any difference in the distribution of pauses of varying length through the winter? Table II shows the percentage distribution of pauses beginning at two days in length, grouped according to the month of origin. The combined values for the three years are shown in the last column. It is clear that the pauses fall into two classes, short and long, the dividing line between the two groups falling at about 10 days. Further, it is evident from the table that the long pauses originate mainly in December and January, and to a less extent in February, but that the short pauses are distributed in a fairly uniform manner throughout the winter.[1] An examination of the pauses occurring in March and April not due to broodiness shows that while all pauses are less numerous than in the winter, and while a few long pauses may be found, most are short ones occurring in practically the same proportions observed in the other months.

[1] The increase in long pauses originating in December and January automatically decreases the percentage of the short pauses so that relatively they are somewhat less numerous in spite of the percentages being about equal.

TABLE II.—*Length of pauses distributed according to month in which they originate, for 1913–14, 1915–16, 1916–17* [a]

Length of pause.	1913–14					1915–16				
	November.	December.	January.	February.	March.	November.	December.	January.	February.	March.
Days.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
2	75.00	68.63	51.54	53.33	48.81	71.15	57.02	53.85	53.81	59.69
3	.....	7.84	19.23	20.00	13.09	9.62	14.91	8.24	15.71	12.25
4	.....	17.65	6.15	9.17	13.09	3.85	3.51	4.95	8.57	7.14
5	.....	1.96	3.85	4.17	4.76	.....	2.63	3.85	1.90	8.16
2–5	75.00	96.08	80.77	86.66	79.76	84.62	78.07	70.88	80.00	87.25
6–10	.....	3.92	4.62	5.83	10.71	1.92	5.26	6.59	5.71	6.12
11–15	12.50	.....	3.08	2.50	1.19	.....	.....	3.30	2.86	3.06
16–20	.....	.....	1.54	1.67	3.57	1.92	.88	3.30	2.38	.51
21–25	.....	.....	3.85	2.50	1.19	1.92	1.75	2.20	1.90	1.02
26–30	.....	.....	.....	.83	2.38	3.85	.88	2.20	3.81	1.02
31–35	.....	.....	6.15	.....	.....	.....	2.63	1.10	1.43	.....
36–40	12.50	.....	.....	.....	.....	1.92	.88	1.65	.95	.51
41–45	.....	.....	.....	.....	.....	.....	.88	2.20	.....	.....
46–50	.....	.....	.....	.....	.....	.....	1.75	2.20	.....	.....
51–55	.....	.....	.....	.....	.....	.....	1.75	.55	.48	.....
56–60	.....	.....	.....	.....	.....	1.92	.88	2.20	.....	.....
61–65	.....	.....	.....	.....	.....	1.92	1.75	.55	.....	.....
66–70	.....	.....	.....	.....	.....	.....	.88	.55	.....	.....
71–75	.....	.....	.....	.....	.....	.....	.....	.....	.48	.....
76–80	.....	.....	.....	.....	.....	.....	.....	.....	.....	.51
81–85	.....	.....	.....	.....	.....	.....	1.75	.....	.....	.....
86–90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
91–95	.....	.....	.....	.....	.....	.....	.....	.55	.....	.....
96–100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
101–105	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
121–125	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
126–150	.....	.....	.....	.....	1.19	.....	.....	.....	.....	.....

Length of pause.	1916–17					Three years combined.				
	November.	December.	January.	February.	March.	November.	December.	January.	February.	March.
Days.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
2	57.78	48.67	51.16	49.06	64.16	62.05	52.90	52.04	51.59	59.76
3	11.11	13.33	15.01	14.98	12.44	10.26	13.12	14.19	16.25	12.47
4	6.67	8.67	5.65	7.12	7.83	5.64	8.39	5.55	8.04	8.45
5	7.40	3.00	3.65	3.37	4.15	5.13	2.80	3.75	3.02	5.84
2–5	82.96	73.67	76.08	74.53	88.48	83.08	77.20	75.53	78.89	86.52
6–10	6.67	5.00	6.64	8.99	6.91	5.13	4.95	6.20	7.20	7.24
11–15	2.96	2.33	2.99	4.12	2.30	2.56	1.51	3.10	3.35	2.41
16–20	1.48	.66	1.00	2.25	2.30	1.54	.65	1.79	2.18	1.81
21–25	1.48	.66	2.33	3.75	.....	1.54	2.15	2.61	2.85	.60
26–30	1.48	.33	2.66	3.75	.....	2.05	1.08	1.96	3.18	.80
31–35	.....	1.66	3.32	1.50	.....	.....	1.72	3.26	1.17	.20
36–40	.....	.66	1.66	.75	.....	1.03	.65	1.31	.67	.....
41–45	.....	1.00	.66	.37	.....	.....	.86	.98	.17	.....
46–50	.....	1.00	1.33	.....	.....	.....	1.08	1.31	.....	.....
51–55	.74	2.00	.....	.....	.....	.51	1.72	.16	.17	.....
56–60	.....	1.66	.33	.....	.....	.51	1.29	.82	.....	.....
61–65	.....	2.00	.33	.....	.....	.51	1.72	.32	.....	.....
66–70	.....	1.33	.....	.....	.....	.....	1.08	.16	.....	.....
71–75	.74	.....	.33	.....	.....	.51	.....	.16	.17	.20
76–80	.....	1.00	.....	.....	.....	.....	.65	.....	.....	.....
81–85	.....	.33	.....	.....	.....	.....	.65	.....	.....	.....
86–90	.....	.33	.....	.....	.....	.....	.22	.....	.....	.....
91–95	1.48	1.00	.....	.....	.....	1.03	.05	.16	.....	.....
96–100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
101–105	.....	.....	.33	.....	.....	.....	.....	.16	.....	.....
121–125	.....	.33	.....	.....	.....	.....	.22	.....	.....	.....
126–150	.....	.....	.....	.....	.....	.....	.....	.....	.....	.20

[a] Broody pauses are not included.

Table III gives certain values of interest in connection with Table II. In particular, the ratios of the number of pauses to the number of birds

laying, in spite of marked differences in the value of the ratios from year to year, are in agreement (with one partial exception) in having lower ratios at each end of the season than in the middle.

TABLE III.—*Number of birds laying and number of pauses*

Item.	1913–14					1915–16					1916–17				
	November.	December.	January.	February.	March.	November.	December.	January.	February.	March.	November.	December.	January.	February.	March.
Number of birds laying	23	104	161	176	683	60	128	179	209	220	145	266	303	352	376
Total number of pauses	8	51	130	120	83	52	114	182	210	196	135	300	301	267	217
Ratio of pauses to number of birds laying (expressed in percentage)	34.7	49.0	81.0	68.2	100	86.6	89.0	101.7	100.0	89.1	93.1	112.7	99.3	75.9	57.7
Number without any pause	15	57	83	95	35	34	61	75	88	112	61	89	133	172	213
Percentage without any pause	65.22	54.81	51.55	53.98	42.17	56.67	47.66	41.90	42.11	50.91	42.07	33.46	43.89	48.86	56.65
Number with one or more pauses	8	47	78	81	48	26	67	104	121	108	84	177	170	180	163
Percentage with one or more pauses	34.78	45.19	48.45	46.02	57.83	43.33	52.34	58.10	57.89	49.09	57.93	66.54	56.11	51.14	43.35

[a] A part of this flock was not trap-nested after March 1.

SIGNIFICANCE OF THE PAUSES

It appears from a consideration of the data presented in the preceding paragraphs that pauses differ in their significance. It seems clear that three classes at least can be distinguished: First, the long pause that is clearly indicative of the presence of a winter cycle. The actual length of this pause in exceptional instances need not exceed three or four days, provided it comes at the proper season of the year, and is preceded by a considerable period of egg production. Ordinarily, however, it exceeds 10 days in length. Second, short pauses which occur at frequent intervals in the records of particular individuals because of their very number must be regarded as having considerable significance (see Table I, sire 6781). This type may be called "multipause" provisionally and is to be distinguished from the type in which production is essentially continuous, even though no sharp dividing line can be drawn between these two groups. It is possible that certain records of the multipause type represent a particular genotype, since there is a pronounced tendency for many multipause records to occur in the same families. This tendency has been particularly marked in a small flock of Brown Leghorns. Another multipause type results from intermittent egg production during the winter pause.

A third class includes those individuals which exhibit only one or two short pauses. Some individual records probably represent extreme variants of the multipause type, others pauses at the end of the winter cycle, but the majority are clearly without particular significance.

NUMBER OF PAUSES PER INDIVIDUAL

In Table IV is shown the number of pauses above two days in length per individual, for each of the three years. The data for each of the three years are divided into three groups, determined by the time at which egg production began. The chief points of interest are: (1) the large percentage of records without a pause even when production begins before January, (2) the progressive diminution in number of individuals as the number of pauses rises, and (3) the agreement with expectation—viz, that those birds that begin to lay early should have more pauses than those beginning to lay later in the season.

TABLE IV.—*Number of pauses per individual (disregarding 1- and 2-day pauses), arranged in three periods, according to the time egg production began* [a]

Number of pauses.	Number of individual pauses in—															
	1913–14						1915–16						1916–17			
	Where production began—						Where production began—						Where production began—			
	Before January.	During January.	During February	Total.	Per cent.		Before January.	During January.	During February.	Total.	Per cent.		Before January.	During January.	During February.	Total.	Per cent.
0	59	29	12	90	47.87		33	32	21	86	32.45		66	26	20	112	27.72
1	34	17	3	54	28.72		61	16	16	93	35.09		111	19	6	136	33.66
2	19	9	1	29	15.43		40	11	1	52	19.62		57	13	1	71	17.57
3	4	5	0	9	4.79		20	3	0	23	8.68		38	5	0	43	10.64
4	1	0	1	2	1.06		5	1	0	6	2.26		18	5	0	23	5.69
5	3	1	0	4	2.13		3	1	0	4	1.51		8	1	0	9	2.23
6										0			1	0	0	1	.25
7							0	1	0	1	.38		5	0	0	5	1.24
8													1	0	0	1	.25
9													3	0	0	3	.74
Total number of pauses				98	52.13					179	67.55					292	72.28
Total number of individuals				188						265						404	

[a] A few records in which production began very early in the fall have been omitted.

In Table V the number of instances of different lengths of pauses is shown.

TABLE V.—*Number of instances of pauses 3 to 5 days in length, 6 to 10, and 11 up*

Number of pauses.	1913–14					1915–16					1916–17					Total for 3 years.
	A (3–5 days).	B (6–10 days).	A+B.	C (11 days up).	A+B+C.	A (3–5 days).	B (6–10 days).	A+B.	C (11 days up).	A+B+C.	A (3–5 days).	B (6–10 days).	A+B.	C (11 days up).	A+B+C.	
1	36	13	49	28	77	63	24	87	80	167	89	50	139	96	235	479
2	13	1	14	3	17	19	5	24	18	42	39	11	50	36	86	145
3	4	0	4	0	4	6	1	7	2	9	15	1	16	9	25	38
4	5	0	5	0	5	2	0	2	0	2	10	0	10	0	10	17
5						1	0	1	0	1	4	0	4	0	4	5
6																0
7																0
8											1	0	1	0	1	1
Total	58	14	72	31	103	91	30	121	100	221	158	62	220	141	361	685

TOTAL LENGTH OF TIME SPENT IN PAUSES

In Table VI the percentage of the flock spending the specified number of days in pauses is given. It should be noted that pauses of one or two days in length have been disregarded in compiling this table. Thus, the row marked zero does not mean that the birds laid continuously or that they had no 2-day pauses, but that the total time spent in pauses, disregarding those of one or two days, was nothing. The same is true for all the other values for the column headed "Total time spent in pauses." An examination of the individual records shows that the 2-day pauses, which might be taken as the lower limit instead of 3-day pauses, are distributed proportionately.

TABLE VI.—*Percentage distribution of the total time spent in pauses*

[Records beginning after January 1 are excluded]

Total time spent in pauses.	Percentage of flock pausing.					
	1913–14		1915–16		1916–17	
	March hatched.	April and May hatched.	March hatched.	April and May hatched.	March hatched.	April and May hatched.
Days.						
0	60.87	53.331	16.22	30.88	15.38	34.08
3–7	13.04	16.67	10.81	11.76	7.69	17.49
8–12	8.70	10.00	4.05	5.88	2.56	4.93
13–17	4.35	1.67	4.05	8.82	.....	4.93
18–22	2.17	6.67	5.41	5.88	2.56	2.69
23–27	.....	1.67	1.35	5.88	2.56	4.93
28–32	6.52	3.33	.....	5.88	2.56	3.59
33–37	2.17	1.67	8.11	7.35	.....	4.93
38–42	2.17	.....	1.35	2.94	2.56	3.14
43–47	.....	1.67	8.11	2.94	2.56	3.14
48–52	.....	.....	6.76	1.47	7.69	2.24
53–57	.....	3.33	2.70	.....	2.56	1.79
58–62	.....	.....	5.41	4.41	2.56	3.14
63–67	.....	.....	5.41	2.94	7.69	3.14
68–72	.....	.....	1.35	.....	5.13	2.69
73–77	.....	.....	2.70	.....	2.56	.....
78–82	.....	.....	1.35	.....	10.26	.45
83–87	.....	.....	5.41	.....	2.56	.....
88–92	.....	.....	.....	1.47	2.56	.90
93–97	.....	.....	1.35	1.47	7.69	.90
98–102	.....	.....	.....	.....	2.56	.....
103–107	.....	.....	1.35	.....	.....	.45
108–112	.....	.....	1.35	.....	.....	.....
113–117	.....	.....	.....	.....	.....	.....
118–122	.....	.....	1.35	.....	.....	.....
123–127	.....	.....	.....	.....	2.56	.....
128–132	.....	.....	1.35	.....	2.56	.45
133–137	.....	.....	1.35	.....	.....	.....
138–142	.....	.....	.....	.....	2.56	.....
143–147	.....	.....	1.35	.....	.....	.....

Several features of this table require comment. First, the large percentage of the 1913-14 flock that falls in the zero class, and the low value of the pause of maximum length. It should be noted that this flock was not put into the laying houses until late October, and none of them began to lay until after November 1. Second, the high percentage of the flocks of the April and May hatches of 1915–16 and 1916–17 that spent practically no time at all in pauses. Thus, the sums of the first two rows are 42.64 and 51.56 per cent, respectively. This high value is the more remarkable for the season of 1916–17, since the birds began to lay early in the fall. Contrasted with this is the third point—viz, the relatively low percentage of the March-hatched pullets of these two years that fall into these rows. This may perhaps be explained by the tendency of March-hatched pullets to begin to lay early in the fall and to undergo a winter molt.[1] That the 1913–14 flocks shows a radically different distribution is probably due to its delay in beginning production. This raises the question as to whether or not the time a bird begins to lay may not have a considerable effect on the appearance or nonappearance of the winter pause. The individual records, however, prove that no necessary relation of the sort postulated exists.

B.—RATE OF PRODUCTION

VALUE OF MONTHLY EGG PRODUCTION AS AN INDEX OF A WINTER CYCLE

A cycle in egg production may be indicated by a lessened daily rate of production as well as by a pause. Specifically one would expect of the winter cycle, if it were delineated only by a change in rate, either that production should begin at a relatively high rate to be followed during the latter part of the winter by a period of lessened production or that the production should start at a slow rate, rise to a maximum, and then decline. Following Pearl, we should anticipate that February would have less eggs than January.

In handling the data given in Tables VII to XI we have proceeded as follows, unless otherwise specified. Each lot of Rhode Island Reds is a group of individuals selected for the following reasons: (1) A laying period of considerable length in order that ample time should be allowed for the completion of the entire cycle—that is, both egg production and pause. Thus, birds beginning to lay after December 1 are excluded from the tables. (2) Records containing broody pauses are excluded. (3) Each month should be equal in length. We utilize, therefore, three periods of 31 days each—viz, the months of December, January, and February, including in the latter the first three days of March. (4) The data, furthermore, are divided into two groups—viz, March-hatched

[1] Possibly the large percentage of March-hatched pullets with pauses may be interpreted as being due to a greater opportunity for the appearance of the winter cycle, since they begin to lay early in the season. Pearl, however, does not mention an association of a molt with the winter pause.

pullets and those hatched in April and May, the hatching date of the latter being the same as for the Maine birds.

The data for Barred Plymouth Rocks and Wyandottes have been extracted from the Maine Station Bulletins 79 and 93 (*3*, *4*) and have been handled in essentially the same way. As these records have been given for months only, only those birds that laid at least one egg in November have been included in the tables. Dr. Pearl has stated to the writer that his Barred Plymouth Rocks do not go broody during the winter, so that we have assumed that broodiness does not enter as a disturbing factor. The February records have been corrected to a basis of 31 days.

TABLE VII.—*Mean monthly egg production of three breeds of pullets beginning to lay before December 1*

[Broody records are excluded. No record is included where production began later than December 1. No Barred Plymouth Rocks or White Wyandottes that failed to lay in November are included. February records are reduced to a 31-day basis]

BARRED PLYMOUTH ROCKS

Flock of—	Hatched.	Number of individuals.	December.	January.	February.
1899–1900		38	17.3	19.4	13.4
1900–1901		33	16.2	15.9	17.6
1901–1902		25	17.2	17.2	11.2
Total		96	16.9	17.6	14.3

WHITE WYANDOTTES

1899–1900		34	18.8	17.4	14.7
1900–1901		58	12.7	16.9	13.4
1901–1902		11	15.8	13.2	12.7
Total		103	15.0	16.7	13.8

RHODE ISLAND REDS

1913–14	March	10	21.1	21.5	20.6
	April and May	13	21.2	21.9	21.6
1915–16	March	56	17.0	14.0	12.9
	April and May	24	19.9	14.9	12.8
1916–17	March	32	11.6	7.9	12.9
	April and May	122	19.3	15.0	16.3
Total		257	18.1	14.5	15.2

From Table VII it is clear that the egg production of February is usually lower than that for January. Some exceptions are to be noted, especially in the Rhode Island Reds, and also for 1900–1901 in the Barred Plymouth

Rocks. The Rhode Island Reds, compared with the Barred Plymouth Rocks and the White Wyandottes, show a less difference between the two months. In this connection it may be noted that the mean value of the February egg production for eight years, as given for the Barred Plymouth Rocks by Pearl (7) if reduced to a basis of 31 days is 12.03, approximately, or slightly higher than for January, which is 11.71. The mean egg production for February (28 days) for the entire flock of our Rhode Island Reds has always been higher than for January.

Table VIII is similar to Table VII, but we have utilized the larger numbers made available by including in the January and February means the records made by birds beginning to lay as late as January 1. The essential result is the same as shown in Table VII.

TABLE VIII.—*Mean monthly egg production of pullets from the same flocks as Table VII, but including those beginning to lay as late as January 1*

BARRED PLYMOUTH ROCKS

Flock of—	Hatched.	Number of individuals laying in—		December.	January.	February.
		December.	January and February.			
1899–1900		38	55	17.3	18.7	11.8
1900–1901		33	56	16.2	15.5	16.5
1901–1902		25	45	17.2	15.4	12.4
Total		96	156	16.9	16.6	13.7

WHITE WYANDOTTES

1899–1900		34	50	18.8	18.3	14.0
1900–1901		58	77	12.7	16.9	14.6
1901–1902		11	31	15.8	16.5	12.7
Total		103	158	15.0	17.2	14.0

RHODE ISLAND REDS

1913–14	March	10	46	21.1	20.5	19.7
	April and May	13	62	21.2	20.6	19.9
1915–16	March	56	90	19.9	14.3	13.5
	April and May	24	70	17.1	16.8	15.3
1916–17	March	32	44	11.6	8.3	11.1
	April and May	122	230	19.3	16.1	17.0
Total		256	542	17.7	14.8	16.0

For the Barred Plymouth Rocks and White Wyandottes the December production varies in the individual years, being sometimes greater,

sometimes less than for January. For the Rhode Island Reds the December production is considerably greater than for January and also for February.[1]

TABLE IX.—*Mean monthly egg production for all Rhode Island Reds that began to lay by December 1, separated into two groups, according to length of pauses*

[Any record having a single pause of more than 10 days in length is included in the group of pauses of 11 days or more. A record having several short pauses of less than 11 days each, even though aggregating more than 10 days, is included in the groups of pauses of less than 11 days]

Flock of—	Grouping of records.	Hatched.	Number of individuals.	December.	January.	February (31 days).
1913–14	All birds		23	21.1	21.7	20.9
	Records with pauses not exceeding 10 days in length.	March	9	21.0	22.0	22.2
		April–May	11	22.6	23.1	22.3
		Hatches combined	20	21.9	22.6	22.3
	Records with pauses of 11 days or more.	March	1	22.0	17.0	1.1
		April–May	2	13.0	15.5	16.5
		Hatches combined	3	16.0	16.0	11.4
1915–16	All birds		80	17.9	14.3	12.9
	Records with pauses not exceeding 11 days in length.	March	20	19.4	19.9	20.0
		April–May	11	19.5	19.2	18.4
		Hatches combined	31	19.5	19.6	19.4
	Records with pauses of 11 days or more.	March	36	15.7	10.8	9.0
		April–May	13	20.3	11.2	8.0
		Hatches combined	49	16.9	10.9	8.7
1916–17	All birds		154	17.8	13.6	15.5
	Records with pauses not exceeding 11 days in length.	March	7	21.7	19.7	20.7
		April–May	69	22.4	21.1	20.9
		Hatches combined	76	21.7	19.7	20.7
	Records with pauses of 11 days or more.	March	25	8.8	4.6	8.8
		April–May	53	15.6	7.2	10.7
		Hatches combined	78	13.4	6.1	10.1

If the data for Rhode Island Reds are analyzed further, as is done in Table IX, certain interesting facts come to light. In this table the records have been divided into two groups, one consisting of those records

[1] A comparison was attempted between November and December egg production, but no satisfactory results could be obtained, because of the small number of birds which had complete records for November.

that have no pauses exceeding 10 days in length, and the second of those that have pauses of more than 10 days. In the former group the egg production remains at essentially the same point in all three months. In the second group, however, the January and February production is markedly lower than that of December. The production for January may or may not exceed that of February.[1]

DIFFERENCES IN MONTHLY EGG PRODUCTION DURING DECEMBER, JANUARY, AND FEBRUARY FOR RHODE ISLAND REDS, BARRED PLYMOUTH ROCKS, AND WHITE WYANDOTTES

In Table X we have examined the differences in the monthly egg production for the same set of birds shown in Tables VII and VIII. For the Barred Plymouth Rocks and White Wyandottes it is noticeable that for each year but one the number of birds laying more eggs in January than February is greater than the number laying more eggs in February than January (in the exception the number is equal) and that in five out of six instances the average number of eggs laid by the birds having an excess January production is greater than for those having an excess production in February. The percentage of birds having an excess January production is 75.29 for Barred Plymouth Rocks and 68.23 for the White Wyandottes.

The data for the Rhode Island Reds are quite different in character. Only 51.39 per cent of the March-hatched pullets lay more eggs in January than February, while for April and May hatched pullets the value is 47.16 per cent, although in two years out of three the number of birds with a January excess is greater than for February. In only one instance, and that with a small number of birds involved, is the number much more than twice the number having an excess February production. This is to be compared with the Maine records, where in every instance the number of birds with a January excess is greater than those with a February excess and, except in two instances, are two to three times as numerous (in one case 16 times). For the Rhode Island Reds hatched in April and May the average number of excess eggs in two years out of three is greater for those pullets with an excess February production. For the March-hatched pullets conditions are reversed.

[1] It is possible that the two groups, high producers and mediocre producers, should be separated in an analysis of this sort. So few of the latter were available, however, that it seemed unwise to attempt the separation.

TABLE X.—*Differences in mean production for the months of December and January, December and February, and January and February for the several flocks studied. All birds began egg production on or before December 1*

RHODE ISLAND REDS

Flock of—	Month hatched.	December greater than January.			December less than January.			December greater than February.				December less than February.			January greater than February.				January less than February.		
		No difference.	Number of individuals.	Total excess.	Mean excess.	Number of individuals.	Total deficiency.	Mean deficiency.	No difference.	Number of individuals.	Total excess.	Mean excess.	Number of individuals.	Total deficiency.	Mean deficiency.	No difference.	Number of individuals.	Total excess.	Mean excess.	Number of individuals.	Total deficiency.	Mean deficiency.
1913–14	March	0	4	10	2.50	6	21	3.50	3	2	8	4.00	5	15	3.00	3	4	14	3.50	3	10	3.33
	April and May	2	4	10	2.50	5	15	3.00	2	6	18	3.00	3	14	4.66	5	5	12	2.40	1	3	3.00
	Total	2	8	20	2.50	11	36	3.27	5	8	26	3.25	8	29	3.62	8	9	26	2.88	4	13	3.25
1915–16	March	2	30	205	6.83	19	69	3.63	2	31	319	10.29	18	100	5.50	5	26	206	7.92	20	121	6.05
	April	1	21	166	7.90	3	19	6.33	1	20	211	10.55	4	24	6.00	0	15	101	6.73	10	51	5.10
	Total	3	51	371	7.27	22	88	4.00	3	51	530	10.39	22	124	5.63.	5	41	307	7.48	30	172	5.73
1916–17	March	1	16	106	6.62	4	20	5.00	0	11	114	10.36	10	84	8.40	2	7	61	8.71	12	117	9.75
	April and May	9	84	560	6.66	26	91	3.50	6	81	483	5.96	32	155	4.84	10	48	224	4.66	61	365	5.98
	Total	10	100	666	6.66	30	111	3.70	6	92	597	6.48	42	239	5.69	12	55	285	5.18	73	482	6.60
	Total	30	159	1,057	6.64	63	235	3.73	28	151	1,153	7.63	72	392	5.44	50	105	618	5.88	107	667	6.23
	Per cent	.....	71.62	.....	.....	28.37	.....	.....	.....	67.71	.....	.....	32.28	.....	.....	.....	49.52	.....	.....	50.47	.....	.....

BARRED PLYMOUTH ROCKS

1899–1900	April and May	2	12	61	5.08	21	133	6.33	1	24	203	8.45	10	60	6.00	1	32	222	6.93	2	7	3.50
1900–1901	April and May	2	15	105	7.00	14	85	6.07	4	14	71	5.07	13	102	7.84	2	15	76	5.06	14	127	9.07
1901–1902	April and May	2	13	70	5.38	8	61	7.62	2	16	155	9.68	5	18	3.60	1	17	149	8.76	5	21	4.20
	Total	6	40	236	5.90	43	279	6.48	7	54	429	7.94	28	180	6.42	4	64	447	6.98	21	155	7.38
	Per cent	.....	48.19	.....	.....	51.80	.....	.....	.....	65.85	.....	.....	34.14	.....	.....	.....	75.29	.....	.....	24.70	.....	.....

WHITE WYANDOTTES

1899–1900	April and May	5	16	113	7.06	11	51	4.04	2	23	189	8.21	7	50	7.14	3	22	130	5.90	7	52	7.42
1900–1901	April and May	4	14	82	5.85	34	269	8.50	4	22	136	6.18	20	216	8.30	4	32	205	6.40	16	78	4.87
1901–1902	April and May	1	6	42	7.00	1	3	3.00	0	5	55	11.00	3	9	3.00	0	4	34	8.50	4	27	6.75
	Total	10	36	237	6.58	46	343	7.45	6	50	380	7.60	36	275	7.63	7	58	369	6.36	27	157	5.81
	Per cent	43.90				56.09			58.13				41.86			68.23				31.76			

A consideration of the number of individuals laying an excess number of eggs for December over January (and also February) shows that more of the Rhode Island Reds have a December excess than a January (or February) excess. For the Barred Plymouth Rocks and White Wyandottes more individuals have a January production in excess of that of December, but a February deficiency. The difference in the case of the Barred Plymouth Rocks, however, is not great. Nevertheless it is clear that the egg production of these two varieties does not undergo a period of depression at the same season as that of the Rhode Island Reds.

TABLE XI.—*Distribution of individuals having a greater egg production in January over February, or vice versa, arranged according to the maximum length of any single pause*

	January production greater than February.									February production greater than January.								
	1913–14			1915–16			1916–17			1913–14			1915–16			1916–17		
Length of pauses..days..	0	3–10	11–up.	0	3–10	11–up.	0	3–10	11–up.	0	3–10	11–up.	0	3–10	11–up.	0	3–10	11–up.
EXCESS NUMBER OF EGGS.																		
1	11	....	....	4	2	2	15	6	5	7	3	2	5	2	2	11	10	3
2	8	1	....	1	4	1	6	6	3	5	1	1	2	2	2	11	7	5
3	4	2	....	3	3	2	7	7	1	5	2	2	6	3	3	8	9	1
4	1	4	....	....	2	3	3	3	2	5	3	....	3	3	1	....	3	8
5	....	2	1	....	2	1	2	1	2	....	3	1	1	2	2	....	3	9
6	....	....	....	1	....	3	1	2	3	....	....	1	....	....	1	1	....	1
7	....	1	1	....	1	6	....	....	3	....	....	....	....	....	2	1	2	5
8	....	....	....	....	2	2	....	....	1	....	....	1	....	....	3	....	....	1
9	....	1	....	....	1	2	....	....	1	....	....	....	....	....	2	....	2	2
10	....	....	....	....	....	3	....	1	....	....	....	....	....	....	1	....	....	1
11	....	....	1	....	....	3	....	....	4	....	....	....	....	....	....	....	....	3
12	....	....	....	....	....	3	....	....	1	....	....	....	....	....	....	....	....	5
13	....	....	2	....	....	3	....	....	4	....	....	2	....	....	1	....	....	4
14	....	....	1	....	....	4	....	....	1	....	....	....	....	....	2	....	....	1
15	....	....	....	....	....	3	....	....	2	....	....	....	....	....	1	....	....	5
16	....	....	2	....	....	2	....	....	1	....	....	....	....	....	....	....	....	1
17	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	3
18	....	....	....	....	....	....	....	....	2	....	....	....	....	....	3	....	....	1
19	....	....	1	....	....	....	....	....	1	....	....	....	....	....	1	....	....	1
20	....	....	....	....	....	1	....	....	1	....	....	....	....	....	1	....	....	2
21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	1
22	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
23	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1	....	....	....
Total	24	11	9	9	17	44	34	26	40	22	12	10	17	12	30	32	36	63
Sum of first two columns in each section	....	35	....	....	26	....	....	60	....	....	34	....	....	29	....	....	68	....
Number with the same production in each month	15	5	0	6	0	4	18	6	9	....	....	....	....	....	....	....	....	....

SUMMARY

	Production equal.			February production greater than January.			January production greater than February.		
Length of pause.....days..	0	3–10	11–up.	0	3–10	11–up.	0	3–10	11–up.
Number of individuals	39	11	13	71	60	103	67	54	93
Sum of first two columns in each section	.....	50	.....	.....	131	.....	.....	121	.....
Sum of all three columns in each section	.....	.....	63	.....	.....	234	.....	.....	214

DIFFERENCE IN JANUARY AND FEBRUARY EGG PRODUCTION, TAKING THE LENGTH OF PAUSE INTO CONSIDERATION

The results of an examination of this point are shown in Table XI, which gives no evidence that a difference in the egg production of an individual for the two months is more likely to occur in one month than the other, since the number of individuals falling in the different categories is approximately equal, although fluctuating somewhat from year to year.

These data, taken in connection with those previously discussed regarding differences in monthly production and with the observations on rate of production, show that a lower rate of production for February over January in the individual case is without significance, unless associated with a definite pause. This information is of particular value for those instances in which the production for February is only a few eggs less than for January and which, from Pearl's data, might be considered to exhibit a winter cycle.

TABLE XII.—*Mean production of two groups of pullets hatched in April, 1916, for the periods after the first egg designated in the headings*

BIRDS BEGINNING TO LAY OCT. 5–DEC. 13, INCLUSIVE (80 TO 72 INDIVIDUALS[a])

Days of production...	1–31	32–62	63–93	1–10	11–41	42–72	73–103	Mean March production.
Mean number of eggs per period.....	16.96	16.60	14.56	4.93	17.63	15.87	15.01	20.81
Mean date of beginning and end of each period.....	Nov. 9 to Dec. 10.	Dec. 11 to Jan. 10.	Jan. 11 to Feb. 10.	Nov. 9 to Nov. 19.	Nov. 20 to Dec. 30.	Dec. 21 to Jan. 30.	Jan. 21 to Feb. 20.	

BIRDS BEGINNING TO LAY DEC. 14–JAN. 25, INCLUSIVE (69 TO 55 INDIVIDUALS[a])

Mean number of eggs per period.....	17.11	17.92	21.68	5.24	17.50	19.28	22.03	
Mean date of beginning and end of each period.....	Jan. 2 to Feb. 1.	Feb. 2 to Mar. 3.	Mar. 4 to Apr. 4.	Jan. 2 to Jan. 12.	Jan. 13 to Feb. 12.	Feb. 13 to Mar. 16.	Mar. 17 to Apr. 16.	

[a] The variation number of individuals is due to broodiness.

EGG PRODUCTION IN PERIODS OF DEFINITE LENGTH, BEGINNING WITH FIRST EGG

In the preceding paragraphs we have used records that begin before a definite date—viz, December 1. On being examined from the standpoint of the first egg it will be observed that the production for any one month, say December, is made up of the production of birds that have been laying for varying intervals of time, including those well along in production and those just beginning. In Table XII the rate of production has been examined from another standpoint. Three periods of

31 days each, beginning with the date of the first egg, and three periods of 31 days each beginning with the eleventh day of production have been employed in studying the production of two groups of April-hatched pullets. One group has a mean date of first egg on November 9; the other, on January 2. The reason for employing two sets of three periods of 31 days, each differing by 10 days, for each lot, lies in the fact that egg production sometimes is extremely slow and erratic at the start and that this may reduce the egg production disproportionately for the first 31-day period.

The following points are shown by Table XII: First, the egg production of the first group is somewhat inferior to that of the second. Note particularly the March production of the first group compared with that period of the second that extends from March 4 to April 4. Second, while there is a fall from the first 31-day period through each of the two successive periods in the first group until March, the second group shows a constant rise from period to period, which may mean that the time of year in which the various periods fall is concerned with the drop in production, for it will be noted that the first period of the second group nearly coincides with the third period of the first group.

CONCLUSIONS REGARDING THE CRITERIA FOR THE WINTER CYCLE IN THE INDIVIDUAL

A consideration of the data presented in the preceding pages leads to the following conclusions regarding criteria by which the winter cycle can be recognized in the individual record.

First. The rate of production, as shown by the monthly egg records, fails to furnish a satisfactory index of the existence of a winter cycle in the individual Rhode Island Red pullet.

Second. The best criterion of the existence of a winter cycle in the individual is the existence of a pause in production beginning in December, January, February, or, rarely, March, following a period of continuous egg production, and usually exceeding 10 days in length. A single pause in some instances may be replaced by series of short pauses separated by only one or two eggs.[1]

Third. In some instances a short pause—that is, 10 days or less in length—occurring in February or March and following a period of several weeks of continuous egg production may delimit the winter cycle.

It seems clear that the period of low flock production for the Rhode Island Reds, for birds beginning to lay sufficiently early in the season may come earlier in the winter than at the Maine Station. In some

[1] The second part of the two recent bulletins from the Utah Station—viz, Ball, Alder, and Egbert (*1*), and Ball and Alder (*2*)—was received after the manuscript of this paper had been completed. Only a very brief comment can be made on their discussion of the "'winter' egg-laying period" in White Leghorns. They conclude "that there is no apparent biological ground for either the beginning or end of this period . . ." This conclusion, which rests on mass statistics, needs reexamination before it can be considered of universal applicability to all White Leghorns.

individuals the pause comes comparatively early in the winter so that the following [spring (?) cf. Pearl and Surface (7)] cycle of production may begin as early as the middle of January. This may mean, perhaps, that the winter pause in Rhode Island Reds is not homologous with that of the Maine Station birds. Whether or not this is so, it would seem desirable to look at it from a somewhat different standpoint. It may be that this pause follows an initial cycle of production. It may be, too, that we are not dealing wholly with an inherent pause but with a pause that depends in part on the environment for its manifestation, which is due to a difference in resistance on the part of individuals to the weather conditions at this season of the year.

NUMBER OF EGGS LAID BEFORE THE WINTER PAUSE AND LENGTH OF WINTER PAUSE

In those instances where the winter pauses could be determined with some degree of accuracy, we have determined the range and mean number of eggs laid before the pause and the same constants for the pause itself, for the pullets of the April and May hatches shown in Table XIII. It should be borne in mind, however, that in most instances the limit specified earlier has been used for the lowest number of days indicative of the winter pause.

For the number of eggs before the pause, the range has a value of 2 to 96,[1] with a mean of 35.98 eggs. The length of the pause has a range of 8 to 72 days, with a mean of 34.23 days. For the birds listed under section B of Table XIII, the values are for eggs; range 1 to 96,[1] mean, 36.98, and for length of pause range, 3 to 104, mean 24.87.

The possibility of a correlation between the number of eggs laid before the pause and the length of the pause has been examined and found to be practically nonexistent.

MODE OF INHERITANCE OF THE WINTER CYCLE

From the data that have been presented in the preceding pages it is clear that some individual Rhode Island Reds exhibit a definite winter cycle, while others as definitely show no winter cycle. For purposes of description we may describe the former as "winter cycle," the latter as "no winter cycle." It is clear, moreover, from an examination of the family records (Tables I and XIII) that the character is inherited and that segregation takes place. When the ratios are examined, however, no evidence of an entirely satisfactory character is afforded us as to the mode of inheritance of the winter cycle, although there is some evidence that the winter cycle is inherited according to the simple

[1] The rather absurd values for the lower end of the range result from the inclusion of a few records that are obviously out of the ordinary but which can not be excluded. The next lower value is 9.

Mendelian scheme, "no winter cycle" being the dominant allelomorph, "winter cycle" the recessive.

Before considering the evidence for this scheme there are certain peculiarities of the character that should be listed.

First. The character does not come to visible expression in the male; hence, his gametic composition can be made out only through a consideration of his maternal ancestors, his daughters, and his sisters.

Second. The character is a physiological one, subject to possible influences by the environment, and perhaps to other internal factors concerned with egg production.

Third. Pauses distinct from those indicative of the winter cycle but likely to be mistaken for them may occur.

Fourth. Difficulties are encountered in classifying certain individual records, such as records with several very short pauses, a single very short pause, a simple slackening in rate of production without any definite pause, and pauses occurring at the limits of the season. In such instances we have proceeded somewhat arbitrarily. There have been excluded, first, all birds that have laid less than 20 eggs after the first of January; second, all birds showing broody pauses; third, March-hatched birds that begin to lay early in the season, and which molt.

TABLE XIII.—*Progeny of individual pairs of birds of flock of 1916–17, showing the number with a winter cycle (P), those without (N), and those on which a definite determination could not be made (X)*

Father.	Mother.	Presence or absence of winter cycle in mother's record as determined by two methods.	Method A.				Method B.				Father.	Mother.	Presence or absence of winter cycle in mother's record as determined by two methods.	Method A.				Method B.			
			P	N	X	Total.	P	N	X	Total.				P	N	X	Total.	P	N	X	Total.
4723	4473	N X.....	6	5	12	23	12	4	7	23	6781	4509	P P.....	1	8	2	11	5	4	2	11
	5476	N P.....	1	9	0	10	2	8	0	10		3719	N X.....	1	2	3	6	2	1	3	6
	5463	N P.....	2	3	2	7	3	3	1	7		3482	N N.....	3	7	4	14	6	5	3	14
	4178	N N.....	3	3	4	10	7	1	2	10	6373	3600	X X.....	2	2	7	11	5	2	4	11
	4845	P P.....	3	8	1	12	5	6	1	12		174	X P.....	2	0	2	4	2	0	2	4
	4138	P P.....	4	6	5	15	5	6	4	15		284	X X.....	1	1	3	5	1	1	3	5
5581	4553	X P.....	0	1	6	7	0	1	6	7	4378	4043	N N.....	2	1	4	7	3	0	4	7
	4533	X P.....	0	5	0	5	0	5	0	5		4754	P P.....	0	0	8	8	0	0	8	8
	5895	X P.....	2	3	2	7	2	3	2	7		4012	N N.....	4	2	5	11	4	2	5	11
	2564	X P.....	3	3	5	11	6	2	3	11		4592	P P.....	1	0	3	4	1	0	3	4
	5771	X P.....	2	4	2	8	4	3	1	8	4786	6684	X X.....	0	0	2	2	0	0	2	2
	4529	X X.....	0	0	6	6	3	0	3	6		5881	X X.....	0	6	2	8	1	5	2	8
	2565	X X.....	1	0	2	3	1	0	2	3	3617	4409	P P.....	0	4	1	5	3	1	1	5
5077	5703	X P.....	1	2	1	4	1	2	1	4		4716	N P.....	0	8	2	10	1	7	2	10
	6840	N N.....	0	0	4	4	0	1	3	4		5230	N P.....	0	2	1	3	1	2	0	3
	6767	N P.....	2	3	0	5	3	2	0	5		6751	N N.....	1	5	1	7	1	5	1	7
6265	5719	N P.....	1	4	7	12	4	4	4	12		6603	N N.....	0	9	1	10	3	6	1	10
	5159	X P.....	1	4	1	6	1	4	1	6	5477	4844	X X.....	2	2	7	11	2	2	7	11
	5982	N N.....	0	4	3	7	3	2	2	7		6366	N N.....	1	3	0	4	1	3	0	4
4354	4518	P P.....	1	3	4	8	3	3	2	8	5240	6404	X X.....	3	4	0	7	4	3	0	7
	5412	X P.....	1	7	1	9	3	6	0	9	5776	6232	P P.....	0	5	3	8	2	3	3	8
	4828	X P.....	2	6	2	10	5	4	1	10		5098	N N.....	0	0	2	2	2	0	0	2
	5090	X P.....	0	8	2	10	3	6	1	10	4882	2532	X P.....	0	13	13	26	4	12	10	26
	4030	N N.....	0	0	2	2	0	0	2	2											
4312	4254	X P.....	0	0	1	1	0	0	1	1			Total...	61	175	158	394	132	140	122	394
	49	N N.....	1	0	7	8	2	0	6	8											

In Table XIII is shown the classification of the flocks of 1916–17, arranged by families. Each individual is classified twice. According to one classification (method A) our endeavor has been to ascertain as closely as our best judgment would permit, the true status of each individual. In method B, however, we have given the benefit of any doubt, to the winter cycle and have listed every bird in the positive column that could possibly be considered as having a winter cycle.

Section A gives the ratio of 61 individuals with a winter cycle to 174 without. This is close to the 1 to 3 ratio—viz, expected 58¾ to 176¼—for a simple Mendelian case of inheritance. According to method B, however, the ratio approaches closely to equality.

Table XIV gives the ratios for the flocks as a whole for 1913–14 and 1915–16, in addition to 1916–17, and the grand total. The years vary somewhat, but the total, 147 to 388, is perhaps merely a deviation from the expected 133¾ to 401¼, the deviation being in the direction expected, on the assumption that birds without the genes for a winter cycle may exhibit a false cycle.

TABLE XIV.—*Number of individuals classified according to the presence or absence of the winter cycle for the years 1913–14, 1915–16, and 1916–17*

Flock of—	Method A.				Method B.			
	Birds with a winter cycle.	Birds without a winter cycle.	Undeterminable.	Total.	Birds with a winter cycle.	Birds without a winter cycle.	Undeterminable.	Total.
1913–14	25	114	85	224	53	99	72	224
1915–16	61	100	139	300	104	79	117	300
1916–17	61	175	158	394	132	140	122	394
Total	147	388	.....	.....	289	318	.....	.....
Expected	133¾	401¼	.....	.....	(?)	(?)	.....	.....

For method B the observed ratio for the three seasons is 289 to 318.

Mass figures of the sort just given are merely suggestive, since the ratio 1 to 3 holds only under certain conditions. However, an examination of the proportions in which the two types occur among the progeny of a single female, and in some instances of the progeny of one male by several females, favors the suggestion given above. At the same time, the gametic constitution of the parents can not be made out with a satisfactory degree of accuracy. To be sure, one can assign a gametic constitution to many individuals, but it is impossible to check these by reference to preceding years, mainly because the number of progeny from a single pair in the earlier years was too small to afford critical evidence. Since prospective matings are likely to furnish critical evidence on the point in question, it seems advisable to defer any attempt at a solution of this phase of the problem for the present.

SUMMARY

(1) An examination of the data published by Gowell confirms the statements of Pearl and Surface (7) and Pearl (5, 6) regarding the presence of a winter cycle in Barred Plymouth Rocks.

(2) The winter cycle is much more characteristic of the Maine flocks as a whole than it is of our Rhode Island Reds, where it can be demonstrated in only a portion of the flock.

(3) The period of decreased flock egg production for Barred Plymouth Rocks and White Wyandottes comes in February. For Rhode Island Reds it may come in January as well as in February.

(4) A pause, or series of pauses, usually exceeding 10 days in length and following a considerable period of regular egg production, is the best index of the existence of a winter cycle in the individual Rhode Island Red.

(5) The rate of production does not furnish a satisfactory index of the presence or absence of a winter cycle.

(6) Evidence is presented which indicates that the winter cycle may be inherited in some definite but undetermined manner.

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DIGESTION OF STARCH BY THE YOUNG CALF

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PREVIOUS INVESTIGATIONS

There is considerable evidence that young animals thrive on a ration containing starch, but a rather extensive search in the literature failed to discover any data concerning the question as to how soon after birth the calf can begin to digest starch. The investigation here described was undertaken for the purpose of ascertaining how early in its life the calf can utilize starch or starch-containing feeds. The practical application, of course, is in supplementing or supplanting the milk ration of the young calf with other feed.

The literature contains many accounts of feeding experiments with young animals where starch alone or as the principal component of some feed has been used. The purposes of these experiments, however, have been largely to determine the effect of starch upon the health, the rate of gain in weight, the cost of raising, or the digestibility of some other component of the ration rather than the actual digestibility of the starch itself. The record of but one experiment was found in which the feces of young starch-fed calves were tested for the presence of starch.

Ewing and Wells [1] report the use of starch in combination with corn silage and cottonseed meal in the ration of 12-month-old steers on digestion trial. In their summary they state that when as much as 47.3 per cent of the net energy of the ration was supplied in the form of starch the iodin test did not indicate the presence of starch in the feces.

There are recorded in the medical literature on the diet and hygiene of children several investigations in which the actual digestibility of starch by children was studied. Kerley, Campbell, and Mason [2] report the examination for starch of 324 stools, collected under controlled conditions at the New York Infant Asylum from 60 children, all under 1 year of age, who had been fed either wholly or in part on barley water. The barley water was prepared by boiling raw barley flour for 1½ hours. The stools were examined for starch by the Von Jaksch iodin test, with

[1] EWING, Perry van, and WELLS, C. A. THE ASSOCIATIVE DIGESTIBILITY OF CORN SILAGE, COTTONSEED MEAL, AND STARCH IN STEER RATIONS. Ga. Agr. Exp. Sta. Bul. 113, p. 269–296, 7 diagr., 1915.

[2] KERLEY, C. G., CAMPBELL, W. C., and MASON, H. N. A FURTHER CONTRIBUTION TO THE STUDY OF STOOLS OF STARCH-FED INFANTS. *In* Jour. Amer. Med. Assoc., v. 47, no. 19, p. 763–765. 1906.

Lugol's solution. Of the 60 children, 33 always gave negative iodin tests, indicating complete utilization of the starch. Among the remainder, 8 usually gave a negative test, 12 usually gave a positive test, and 7 always a positive test for starch. Of the 41 children showing a good capacity for starch utilization one 19-day-old child received 9.2 gm. of barley flour daily for 2 days; one 21-day-old child received 14.6 gm. every 24 hours; one child 1 month and 22 days old received 25.9 gm. the first day and 25.3 gm. a day for the following four days; and another child 1 month and 19 days old received 12 gm. daily for three days.

Heubner,[1] in a paper presented before the Berlin Medical Society, describes an investigation conducted at Leipzig for the purpose of determining the digestibility of starch in the food of artificially fed children. The children received during 1-day and 2-day periods a carefully prepared starchy gruel which was fed in place of milk, at the same intervals and in the same quantity as the milk feeding. Carbon was used to identify the experimental stools, and the feces from each child were assembled, dried, and analyzed for starch. A 7-weeks-old child received 24.6 gm. of rice flour during a 25-hour period, and no starch was found in the feces. Another child 14 weeks old received 53 gm. of rice flour during a 39-hour period, and 0.1689 gm. of starch was found in the feces. A third child 1 year old received, in addition to 72 gm. of butter, 133 gm. of rice flour during a 48-hour period, and 0.2804 gm. of starch was found in the feces. A fourth child, 14 weeks old, received 57 gm. of a specially prepared oatmeal during a 34-hour period, and 0.2611 gm. of starch was found in the feces.

In an elaboration of the work done by Heubner at Leipzig, Carstens[2] gives the results of digestion experiments on eight children from 5 to 14 weeks old. Some of these children received starch from rice flour, some from a prepared oatmeal flour, and some from two different proprietary infant foods. The same methods were followed as in the Heubner investigation. The quantity of undigested starch varied from a trace in the feces of two children, one 9 weeks and one 15 weeks old, respectively, to 5.08 gm., or 6.23 per cent of the amount ingested by a child 6½ weeks old.

Krüger[1] who worked with fetal and newborn calves found that the ptyalin is secreted in the salivary glands as early as the seventh month of fetal life, but that while the quantity increases up to birth, even at that time it is too small to be of any importance in the digestion of food.

[1] HEUBNER, O. UEBER DIE AUSNÜTZUNG DES MEHLS IM DARM JUNGER SÄUGLINGE. *In* Berlin. Klin. Wchnschr., Bd. 32, No. 10, p. 201–204, 1895. Literatur, p. 204.

[2] CARSTENS, J. H. WEITERE ERFAHRUNGEN ÜBER DIE AUSNÜTZUNG DES MEHLS IM DARME JUNGER SÄUGLINGE. *In* Verhandl. Gesell. Kinderheilk., Bd. 12, p. 169–176. 1895.

[1] KRÜGER, Friedrich. DIE VERDAUUNGSFERMENTE BEIM EMBRYO UND NEUGEBORENEN. 80 p. Wiesbaden, 1891. Literatur, p. 79–80.

EXPERIMENTAL WORK

Two male calves, each 4 days old, were selected. Each was fed 5.44 kgm. of whole milk a day in two feedings. Beginning at 4 days of age, each calf received 40 gm. of ordinary cornstarch per feeding, in addition to the milk, for a period of three days. The starch ration was prepared as follows: The weighed quantity of cornstarch was placed in a pail and mixed with a little milk, then the bulk of the milk was added and the mixture well stirred. The calf consumed the mixture with eagerness and without any apparent digestive disturbance. To make sure that all the starch was consumed, the pail was rinsed once or twice with milk and the calf permitted to drink the rinsings. The starch-feeding period was followed by a rest period of about five days, during which only whole milk was fed; then the calves again received starch in addition to their whole-milk ration exactly as in their first 3-day period. The length of the periods and the duration of the

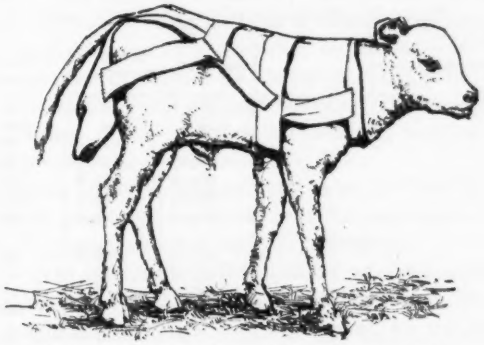

FIG. 1.—Bag for receiving feces and harness for supporting it.

experiment are shown in Table I. The cornstarch fed to calf 1 contained, according to analysis, 77.02 per cent of pure starch, and that fed calf 2, 76.32 per cent. The feces were received in a closely fitting rubber bag supported by a harness as shown in figure 1. Collections were made during the three starch-feeding days and the three days following. The feces were removed from the bag each day and immediately dried on the premises in an electric oven at about the temperature of boiling water. The dried feces, representing a starch-feeding period and the three subsequent days, were united and ground in a mill. The analyses were made according to the methods adopted by the Association of Official Agricultural Chemists, the malt-diastase method being selected for the starch determinations.

The feeding was conducted at the Bureau of Animal Industry's Experiment Farm, Beltsville, Md., and the analytical work was done at the Dairy Division laboratories in Washington. The results are given in Tables I and II.

TABLE I.—*Composition of feces of calves*

Animal and period.	Age of calf when feces were collected.	Weight of dry feces.	Nitrogen in feces.		Ether extract in feces.		Starch in feces.	
CALF 1:	*Days.*	*Gm.*	*Gm.*	*Per cent.*	*Gm.*	*Per cent.*	*Gm.*	*Per ct.*
1	4	288.98	14.07	4.87	6.36	2.20	144.2	49.91
2	12	270.28	13.74	5.08	11.95	4.42	101.5	37.56
3	20	244.87	14.20	5.80	13.75	5.62	67.8	27.70
4	30	179.40	11.66	6.50	7.36	4.10	15.2	8.49
5	39	202.00	17.25	8.54	14.71	7.28	2.2	1.07
CALF 2:								
1	4	283.49	14.27	5.03	12.08	4.26	146.0	51.48
2[a]	14	.....	.....	.....	.....	.....	.....	.....
3	23	190.21	13.54	7.12	24.25	12.75	6.7	3.53
4	31	152.95	10.28	6.72	17.58	11.49	1.6	1.03

[a] Sample was lost at the farm.

TABLE II.—*Proportion of starch digested by calves*

Animal and period.	Starch fed.	Starch in feces.	Starch digested.	
CALF 1:	*Gm.*	*Gm.*	*Gm.*	*Per cent.*
1	184.9	144.2	40.7	22.02
2	184.9	101.5	83.4	45.11
3	184.9	67.8	117.1	63.34
4	184.9	15.2	169.7	91.79
5	184.9	2.2	182.7	98.81
CALF 2:				
1	183.2	146.0	37.2	20.30
2[a]	183.2	.....	.....	.....
3	183.2	6.7	176.5	96.32
4	183.2	1.6	181.6	99.10

[a] Sample was lost at the farm.

CONCLUSIONS

The figures in Table II for digested starch show that the calves when from 4 to 7 days old were able to digest about one-fifth of the quantity consumed; in one case 22.02 per cent and in the other 20.30 per cent. When calf 1 was 12 to 15 days old, the percentage of starch digested had more than doubled and when 3 weeks old it had nearly tripled, while at 4 weeks in the case of calf 1 and at 3 weeks in calf 2, the percentage of starch digested was well over 90.'

While it is quite probable that a calf but a few hours old can not digest an appreciable amount of starch, it can readily be seen that the quantity of starch-splitting enzyms must increase very rapidly in the first few days of life, for the calves under experiment, when only 3 to 4 weeks old, were able to digest a ration nearly 10 per cent of the dry matter of which was starch.

These results indicate that the milk ration of a calf but a few days old may be supplemented with a starchy food and that the starchy material may be rapidly increased as the calf grows older.

TOXICITY OF VOLATILE ORGANIC COMPOUNDS TO INSECT EGGS[1]

By WILLIAM MOORE, *Head of Section of Research in Economic Zoology*, and SAMUEL A. GRAHAM, *Assistant in Entomology, Minnesota Agricultural Experiment Station*

INTRODUCTION

A general survey of the literature has failed to reveal any extensive study of the toxicity of different materials to insect eggs. Certain spray solutions have been studied, but they have been considered individually and not in comparison with other related compounds.

Cooley (*1*)[2], working with the oyster-shell scale (*Lepidosaphes ulmi* L.) has shown that linseed oil, cottonseed oil, and lime-sulphur were effective. In the cases of the oils some of the eggs were killed, while other eggs hatched, but the young insects died during or shortly after emergence. Lime-sulphur failed to kill the eggs, but the young were killed very soon after hatching. Pure kerosene apparently had no effect on the eggs.

Gillette (*2*), working with aphid eggs of different species, has shown that eggs treated with kerosene emulsion containing less than 25 per cent of keresene were unaffected by the spray. Scalecide, Thompson's Soluble Oil, lime-sulphur, and different soaps had little effect unless used in very large doses. Tobacco extracts containing nicotine or nicotine sulphate were found to be very effective.

Safro (*9*), in the study of lime-sulphur as an ovicide for the codling moth (*Carpocaspa pomenella* L.), shows that this material is only effective to eggs in which the embryo is almost fully developed.

Woodworth (*10*) has studied the toxicity of hydrocyanic-acid gas to the eggs of scale insects, but does not consider the factor of age.

Recently particular attention has been given to the study of the toxicity of volatile organic compounds to the eggs of lice (*Pediculus capitis* and *P. corporis*, and *Phthiris pubis*). Kerosene has been used against head lice and their eggs for many years, but in the recent work many other materials have been recommended.

Postnikov (7) recommends amyl alcohol, ethyl alcohol, benzene, chloroform, carbon tetrachlorid, methane, and birch tar for the destruction of head lice and their eggs. Gasoline has been used for the destruction of the eggs of the clothes louse, and Kinloch (*4*) claims that immersion in this material for one minute will kill, while exposure to its vapor is fatal in one-half hour. He considers that benzene, toluene,

[1] Published, with the approval of the Director, as Paper 88 of the Journal Series of the Minnesota Agricultural Experiment Station.

[2] Reference is made by number (italic) to "Literature cited," p. 586–587.

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and acetone are as toxic as gasoline. Von Prowazek (*8*) recommends xylol and ether for the destruction of lice and their eggs.

In view of the work of the senior author (*5, 6*) showing that the toxicity of organic compounds to insects is related to their volatility, of which the boiling point is a general index, it was thought advisable to make a similar study of the toxicity of a series of volatile organic compounds to insect eggs.

METHOD OF EXPERIMENTATION

For these experiments it was considered desirable to use eggs which were not protected from the action of the chemical by any covering. Eggs of the bedbug and the clothes louse were considered; but, owing to the fact that many of these eggs were found to be infertile under the artificial conditions of breeding, and, further, that they were hard to obtain in large enough quantities for the purpose of the experiments, they were discarded. Potato-beetle eggs (*Leptinotarsa decemlineata* Say) were finally decided upon as fulfilling all requirements. As many as 50,000 eggs were used in these experiments, and it was found that in every case untreated eggs hatched 100 per cent. They were also convenient to use, as a cluster of 20 to 30 or more eggs could be easily treated as a unit. The effects of the chemicals were studied in three different ways:

1. By dipping the clusters in the chemical to be tested.
2. By spraying the clusters with the chemical by means of an atomizer.
3. By exposing the eggs to the action of the vapor of the chemical.

In the exposure to the vapor the eggs were fumigated in a similar manner to that employed in the study of the toxicity of the vapor to houseflies recorded in a previous paper (*6*). It was found necessary, however, to use a longer time limit than 400 minutes, 15 hours being finally selected for this purpose.

Eggs were fumigated for 15 hours with varying quantities of the chemical, after which they were removed from the flask and placed in open pasteboard pill boxes until they hatched or were undoubtedly dead. The smallest dose necessary to kill the eggs in this length of time was thus determined and reduced to millionths of a gram-molecule, making possible an accurate comparison of the different chemicals used. In experiments where the eggs were dipped or sprayed they were placed in open pill boxes after treatment and handled in a manner similar to those fumigated.

RESULTS OF THE EXPERIMENTS

The results of dipping and spraying the eggs are given in Table I. The compounds used are arranged in the order of their boiling points, from the lowest to the highest. It will be noted that in general the eggs treated with compounds having the lowest boiling point—that is, the most volatile compounds, permitted most, if not all, of the eggs to hatch. Exceptions may be noted of compounds extremely active

chemically, such as allyl alcohol, which contained ammonia as an impurity, and chlorpicrin. In general those sprayed showed a higher percentage of hatching than those dipped. Some compounds of this series, the vapor of which had been previously shown (*6*) to be nontoxic to houseflies, owing to the fact that they formed gummy masses on exposure to the air, were found to be toxic to the insect eggs. Pinene, terpineol, and geranyl acetate are examples of such chemicals. Further, it is noted that compounds which are so slightly volatile, owing to their high boiling point, that they were ineffective against flies, were found to be toxic to the insect eggs. Such chemicals were eugenol, alpha naphthol, ethyl ether, and trimethylene cyanid. These compounds are only effective, however, when brought into actual contact with the eggs, as in spraying or dipping, and are no more effective as a fumigant against the eggs than they are against adult insects.

TABLE I.—*Relation of the boiling point to the toxicity of organic compounds used in dips and sprays for potato-beetle eggs*

Organic compound.	Boiling point.	Percentage hatching from eggs dipped and removed immediately.	Percentage hatching from eggs sprayed.	Organic compound.	Boiling point.	Percentage hatching from eggs dipped and removed immediately.	Percentage hatching from eggs sprayed.
	°C.				°C.		
Ethyl ether	35	100	100	Trimethylene bromid	165	0	....
Ethyl mercaptan	36. 2	97	100	Terpineol	168	0	....
Carbon bisulphid	46	.....	100	Benzonitrile	170	0	....
Petroleum ether	40–70	100	....	Thiophenol	172. 5	0	....
Acetone	56. 3	88	100	Benzaldehyde	179. 1	0	....
Chloroform	61	95	100	Anilin	182	0	....
Methyl alcohol	66. 5	85	100	Ortho-bromtoluene	182	17	0
Carbon tetrachlorid	78. 1	.....	100	Valeric acid	184. 5	0	....
Ethyl alcohol	78. 4	100	100	Ortho-creosol	190	0	....
Gasoline	70–90	44	88	Iodobenzene	193	0	....
Benzene	80. 3	100	100	Salicylic aldehyde	196	0	....
Thiophene	84	100	0	Para-cresol	201. 8	0	....
Allyl alcohol	97	0	....	Meta-cresol	202. 8	0	....
Amyl nitrite	98	50	0	Nitrobenzene	205	0	0
Nitromethane	101	100	....	Benzyl alcohol	206. 5	0	....
Propyl acetate	102	100	100	Kerosene	150–300	83	100
Toluene	111	0	100	Ortho-nitrotuluene	223	0	....
Chlorpicrin	112	0	0	Bromxylene	225	.....	0
Pyridin	116. 7	.....	16	Citral	225	0	....
Acetic acid	119	100	0	Quinolin	239	0	....
Chlorbenzene	132	0	....	Eugenol	247. 5	0	....
Amyl alcohol	137	0	20	Nitroxylene	250	0	....
Xylene	140	74	100	Nicotine	250	0	0
Amyl acetate	148	.....	100	α-Napthol ethyl ether	272	0	....
Bromoform	151. 2	.....	20	Trimethylene cyanid	274	0	....
Pinene	160	0	....	Geranyl acetate	.....	0	....
Ethyl malonate	160	0	0	Brommethylphenyl-ketone	.....	0	....
Allyl isosulphocyanate	161	.....	0	Ethyl aceto-acetate	.....	0	....
Furfural	162	0	0				
Butyric acid	163	0	0				

Kerosene, although having a high boiling point of 150° to 300° C., allowed 83 per cent of the dipped eggs and 100 per cent of the sprayed eggs to hatch.

TABLE II.—*Toxicity of various organic compounds to eggs of different ages when dipped for various periods*

Compound.	Age.	Percentage hatching after dipping for—						
		1 second.	5 second.	10 seconds.	15 seconds.	30 seconds.	60 seconds.	120 seconds.
Ether	Fully developed embryos	100	100	100	100	.....	.....	.....
	Partially developed	100	0	100	100	.....	.....	.....
	Freshly laid	0	0	0	0	.....	.....	.....
Carbon bisulphid	Fully developed	100	100	0	100	.....	.....	.....
	Partially developed	100	0	0	0	.....	.....	.....
	Freshly laid	100	0	100	0	.....	.....	.....
Methyl alcohol	Fully developed	100	100	100	.....	.....	100	100
	Partially developed	100	100	100	.....	.....	100	100
	Freshly laid	100	100	100	.....	.....	0	100
Chloroform	Fully developed	0	100	100	100	0	100	0
	Partially developed	100	100	100	100	0	0	100
	Freshly laid	.....	100	0	0	100	0	0
Carbon tetrachlorid	Fully developed	.....	3	.....	12	0	5	0
	Partially developed	.....	100	.....	100	100	100	100
	Freshly laid	100	0	.....	0	100	100	0
Benzene	Fully developed	100	100	.....	.....	100	.....	.....
	Partially developed	100	0	.....	.....	0	.....	.....
	Freshly laid	100	0	.....	.....	100	.....	.....
Toluene	Fully developed	100	100	.....	.....	0	.....	.....
	Partially developed	100	100	.....	.....	100	.....	.....
	Freshly laid	100	100	.....	.....	100	.....	.....
Acetic Acid	Fully developed	0	0	.....	.....	0	.....	.....
	Partially developed	0	0	.....	.....	0	.....	.....
	Freshly laid	0	0	.....	.....	0	.....	.....
Xylene	Fully developed	100	0	.....	.....	0	.....	.....
	Partially developed	100	100	.....	.....	32	.....	.....
	Freshly laid	100	100	.....	.....	0	.....	.....
Ortho-bromtoluene	Fully developed	0	0	.....	.....	0	.....	.....
	Partially developed	0	0	.....	.....	0	.....	.....
	Freshly laid	0	0	.....	.....	0	.....	.....

In the experiments it was noted that compounds with low boiling points evaporated from the surface of the eggs very quickly, this giving the material very little time to penetrate. On the other hand, compounds with high boiling points remained upon the eggs for hours, or even days. In view of this fact, a series of experiments was conducted with the lower boiling-point compounds, in which the eggs were dipped

for periods from 1 to 120 seconds, eggs of different ages being used. The results are given in Table II. This table shows that in general with compounds of very low boiling points the freshly laid eggs or those containing embryos only partially developed were more easily killed than those in which the embryo was fully developed. Gortner and Banta (*3*), in working with the toxicity of certain phenolic compounds to amphibian eggs, found that the youngest eggs were more susceptible than the older eggs. This may be due to disturbances in the permeability of the egg, and compounds with low boiling points such as ether would have more influence on the permeability than compounds with higher boiling points. With an increase in the boiling point it was found that the eggs in which the embryo was fully developed were most easily killed. Compounds with very high boiling points, such as nicotine and kerosene, often remained on the eggs and killed the larvæ in the act of hatching. It seems that compounds with high boiling points are not able to penetrate the egg as readily as compounds having low boiling points. In general a slightly longer exposure to the chemical will result in the death of a larger number of eggs.

In these experiments the writers they have been unable to remove compounds of high boiling points from the surface of the egg without injury to the egg, and, hence, have no data as to the length of time necessary to kill with these compounds.

TABLE III.—*Toxicity of kerosene to eggs of various ages*

Age of eggs.	Percentage hatching after dipping for—					
	1 min.	5 min.	10 min.	15 min.	30 min.	Brand.
1 day	0	0	100	0	.....	Unknown.
2 days	.....	100	100	100	.....	Do.
3 days	100	0	100	100	.....	Do.
4 days	.....	13	100	100	.....	Do.
Freshly laid	100	100	100	100	100	Do.
Slightly developed	100	100	0	0	100	Do.
Well developed	33	0	100	0	0	Do.
Spiracles visible through shell	0	0	0	0	0	Do.
Within 1 day of hatching	100	.....	.....	.....	.....	Pearl oil.
Within 2 days of hatching	100	.....	.....	.....	.....	Do.
Within 3 days of hatching	100	.....	.....	.....	.....	Do.
Within 4 days of hatching	100	.....	.....	.....	.....	Do.

A special study was made of the action of kerosene on the eggs, inasmuch as it was a high-boiling-point compound which did not always kill. The results of dipping eggs of different ages in kerosene are given in Table III. Eggs 1 day old in general did not hatch after being dipped. Eggs classed as freshly laid, which may have been 1 or 2 days old, hatched in every case, while eggs with well developed or fully developed embryos failed to hatch. This is interesting in that by killing the young eggs it

acts in a similar manner to compounds with a low boiling point, while by killing the eggs with fully developed embryos it acts as a compound having a high boiling point. The Pearl oil used in the experiments is a product from the California oil fields and therefore differs chemically from the other kerosenes used.

In order to obtain further data on the toxicity of kerosene to eggs, two brands of kerosene were broken up into fractions of different boiling points. The two brands used were Pennsylvania Best sold by the Pure Oil Co. and Perfection oil put out by the Standard Oil Co. of Indiana. The data obtained by this experiment are shown in Table IV. The fraction of Pennsylvania Best boiling between 140° and 187° C. killed only freshly laid eggs. The fraction between 187° and 234° C. killed both the fully developed and freshly laid eggs, while the fraction between 234° and 280° C. killed all the eggs. Apparently the lower fraction did not remain long enough upon the fully developed eggs to produce any influence. It was noted in the kerosene experiments that the higher fractions killed at the time of hatching. This may explain the fact that the partially developed eggs treated with the second fraction allowed 100 per cent to hatch. These eggs being too far developed were not effected by changes in permeability such as would kill a freshly laid egg, while the compound had sufficient time to evaporate from the surface of the egg before the emergence of the larva.

TABLE IV.—*Toxicity of different fractions of kerosene on eggs of different ages*

Brand.	Age.	Percentage hatching after dipping for 5 seconds in fractions with boiling points of—				
		140°–187° C.	187°–234° C.	234°–280° C.	Residue above 280° C.	Undistilled.
Pennsylvania Best	Fully developed	100	0	0	.....	0
	Partially developed	100	100	0	.....	0
	Freshly laid	0	0	0	.....	0
	General	100	100	0	0	100
	do	100	100	100	0	50

Brand.	Age.	Percentage hatching after dipping for 5 seconds in fractions with boiling points of—		
		135°–183° C.	183°–231° C.	231°–280° C.
Perfection	Fully developed	0	0	0
	Partially developed	100	100	0
	Freshly laid	0	0	0

The Perfection oil killed both the fully developed and freshly laid eggs, leaving the partially developed uninjured except for the fraction between 231° and 280° C. Other experiments with these two oils, which will be published later, have shown that the Perfection oil is more toxic than the Pennsylvania Best. Kerosene therefore has oils of low boiling points which kill the freshly developed eggs and oils of high boiling points which destroy the fully developed eggs, while the partially developed eggs are most likely to hatch.

Nineteen compounds were tested to determine the toxicity of their vapor to insect eggs. The results of these experiments are given in Table V, in which the compounds are arranged according to their boiling points, from the lowest to the highest. The increase in toxicity with an increase in boiling point is indicated by the smaller portion of a gram-molecule necessary to kill in 15 hours. That the boiling point is not so good an index of the toxicity of a chemical as its volatility is shown in Table VI, where the compounds are arranged according to their volatility, from the most volatile to the least volatile. A comparison of the two tables shows a better correlation between volatility and toxicity than between boiling point and toxicity. As was found in the work with the housefly (5), chemicals having low boiling points are more valuable for fumigation purposes due to the fact that a larger amount of the vapor may be contained in the air.

TABLE V.—*Toxicity of the vapor of certain organic compounds (in millionths of a gram-molecule required to kill in 15 hours' exposure). Compounds arranged according to their boiling points*

Compound.	Boiling point.	Toxicity (millionths of a gram-molecule).	Compound.	Boiling point.	Toxicity (millionths of a gram-molecule).
	°C.			°C.	
Ethyl ether	35	3,468.2	Toluene	111	104.0
Carbon bisulphid	46	555.5	Chlorpicrin	112	2.8
Petroleum ether	40–70	243.2	Chlorbenzene	132	160.8
Acetone	56.3	1,363.0	Xylene	140	29.5
Chloroform	61	558.0	Bromoform	151.2	3.9
Methyl alcohol	66.5	1,232.0	Furfural	162	1.8
Carbon tetrachlorid	78.1	404.0	Nitrobenzene	205	2.7
Ethyl alcohol	78.4	284.0	Nitroxylene	250	3.3
Gasoline	70–90	41.1	Nicotine	250	1.8
Thiophene	84	344.0			

TABLE VI.—*Toxicity of the vapor of certain organic compounds (in millionths of a gram-molecule required to kill in 15 hours' exposure). Compounds arranged from the most volatile to the least*

Compound.	Toxicity (millionths of a gram-molecule).	Compound.	Toxicity (millionths of a gram-molecule).
Ethyl ether	3,468.2	Chlorbenzene	160.8
Petroleum ether	243.2	Toluene	104.0
Methyl alcohol	1,232.0	Xylene	29.5
Acetone	1,363.0	Gasoline	41.1
Carbon bisulphid	555.0	Bromoform	3.9
Chloroform	558.0	Furfural	1.8
Carbon tetrachlorid	404.0	Nitrobenzene	2.7
Ethyl alcohol	284.0	Nicotine	1.8
Chlorpicrin	2.8	Nitroxylene	3.3
Thiophene	344.0		

Fumigation in a saturated atmosphere with ether, ethyl mercaptan, carbon bisulphid, benzene, carbon tetrachlorid, and chloroform will kill all the eggs in one hour.

SUMMARY

(1) In general, compounds with high boiling point and slight volatility are more effective in dipping and spraying insect eggs than compounds with low boiling point and high volatility.

(2) Compounds with low boiling points kill freshly laid eggs more readily than eggs in which the embryo is partially or fully developed.

(3) Compounds of higher boiling points are more toxic to eggs with fully developed embryos than they are to eggs in which the embryo is only slightly formed.

(4) Kerosene containing both high and low boiling points is destructive to both young and old, but is only slightly toxic to partially developed eggs.

(5) The toxicity of the vapor of organic compounds to insect eggs is related to the boiling point and the volatility. As the boiling point increases and the volatility decreases, the toxicity increases.

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CORN-STOVER SILAGE

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INTRODUCTION

The ensiling of corn stover and cured corn fodder is not a new idea. In a few localities farmers have followed this practice to a limited extent for some years, and there have appeared several Experiment Station publications which deal briefly with the process. Experimental data on the subject are, however, very meager; little has been established with reference to the practicability of stover silage, while nothing is known concerning the nature of the fermentation which takes place and the factors operative other than what may be deduced from knowledge of ordinary silage. The present necessity for more economic production, with the conservation of concentrates and the utilization of more roughage in the live-stock and dairy industries, makes a reconsideration of corn-stover silage of especial pertinence.

The object of the present study was partly to test the practicability of ensiling stover, and partly to determine the nature of the fermentation which takes place therein.

PRACTICABILITY OF ENSILING CORN STOVER

The stover used in this experiment was ensiled early in April, 1916; the material had been kept in a shed since fall and was quite dry. The condition of the material was not good; it was moldy in spots and on the whole represented an inferior grade of stover. This stover was run through a silage cutter and packed in the silo by means of tramping. Water was added in a continuous stream through a hose which was carried and the water distributed by the man who did the packing. A water meter was attached to the hose so as to enable the regulation of the amount used. A wooden-stave silo 16 feet in diameter was filled with 32,000 pounds of stover to which were added 66,000 pounds of water.

Samples of the silage, which were taken at frequent intervals, were examined for general appearance, texture, and aroma. The stover was soon observed to undergo a fermentation with the formation of a product quite similar to normal silage made with green corn. The material softened, regained a slightly greenish color, and developed an aroma simulating that of normal silage, though inferior in all these respects to silage made in the usual way from green corn.

Feeding tests made at the end of the experiment showed that cattle ate this silage with little waste and apparently with a relish. While

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it is not believed that the stover silage is as palatable as is that made from fresh corn, it did prove to be a very acceptable feed which was preferred by cattle to any of the dry roughages furnished. Some experiments in which the actual feeding value of stover silage is determined in comparison with ordinary silage and other roughages are desired, and it is hoped that such tests may be carried out at this Station in the near future.

The keeping quality of stover silage appears to be excellent, provided sufficient water is added. Although, as is the case with other types of silage, the surface material undergoes a moldy spoilage accompanied with heat formation, this condition does not extend to more than the ordinary depth. The silage made in this experiment was not all used during the following winter, and the remaining material, at the time of this writing nearly 1½ years old, is still in excellent condition. In view of the very satisfactory results obtained with such an inferior raw product, we do not hesitate to predict success in the ensiling of any stover which is in reasonably good condition.

Probably the most important consideration for the successful production of stover silage is the amount of water to add. This obviously will vary according to the quantity of water contained in the stover, and this factor should be taken into consideration. While it would be more scientific and exact to determine the most desirable amount of water to add by means of moisture tests on the stover, such a recommendation would find no place in farm practice. In our experimental silo the proportion was about 2 parts of water to 1 of stover, but the stover was probably somewhat drier than would usually be the case. As may be seen from the moisture determinations, which are reported in another section (Table I), the quantity of water added was none too much; in general appearance and to the touch some of the samples seemed to be considerably below the most desirable point.

A laboratory test was carried out upon this point by making stover silage in small jars with varying quantities of water and examining after about one month for general appearance and condition of moisture. The stover used in these tests was very dry. Samples which were made with equal parts by weight of water and stover, as well as those made with 1½ parts of water to 1 of stover were too dry to undergo a typical fermentation and form good silage. Those which had water in the proportion of 2 parts to 1 of stover made good silage, but did not appear to have as much moisture as would be best. Samples put up with 2½ and with 2¾ parts by weight of water to 1 part of stover were in good condition when opened and apparently did not contain an excess of water.

It seems that in general, when reasonably fresh stover is used, about 2 parts of water by weight to 1 of stover would be advisable, while for older and drier stover a slightly larger proportion of water may be more

desirable. It should be kept in mind that these tests were all made with rather dry stover. In the case of ensiling soon after the corn is husked, 2 parts of water might be too much. However, it appears from our observations that there is less danger of adding too much water than of getting too small an amount, and that considerable water may be added above the required amount without injury to the product.

The water should be added uniformly as the silo is being filled so that all the dry cut stover becomes thoroughly wet down. If this precaution is not taken, the water may follow channels down through the silage and waste away at the bottom of the silo. In such an instance spoiled silage might result in some parts of the silo because of an insufficient amount of water.

FERMENTATION OF STOVER SILAGE

To obtain information on the nature of the fermentation which takes place in silage made from stover, determinations were made of the volatile and nonvolatile acids, temperatures, and numbers and types of bacteria at various stages of the ripening process.

Samples for examination were obtained by means of a 2-inch auger provided with an extension shaft of 8 feet, thus making it possible to penetrate to the center of the silo. By repeatedly boring in a short distance and withdrawing the auger until the center of the silo was reached, no difficulty was experienced in securing sufficient material for the different tests. The sample obtained in this way represented the silage mass from the wall to the center of the silo. Not more than one boring was made in one place, the different samples being removed at points all the way around the silo and from 3 to 8 feet from the ground. The material so obtained was subjected to pressure in an ordinary lard press and sufficient juice collected for the various examinations made.

ACID FORMATION.—There can be no doubt that the amount and character of acids in silage influence its quality profoundly. Since it has been the general experience that extremely green corn produces a very sour silage, while corn more nearly mature produces a silage with less acid and of a much better quality, the acid fermentation in silage made from dry material is of interest.

The volatile acidity was determined by subjecting a 100-gm. sample of juice to steam distillation under reduced pressure until 4 liters of distillate were secured. These were titrated directly after collection with *N/10* barium hydrate, with phenolphthalein as the indicator. The nonvolatile acidity was obtained by the difference between the volatile acidity and a total acid determination made by the titration of 20 gm. of juice, diluted to 500 c. c. with carbon-dioxid-free water, against *N/10* barium hydroxid. In Table I the nonvolatile and volatile acids (calculated as lactic and acetic, respectively) are reported in terms of percentage of air-dry material.

TABLE I.—*Acid formation in stover silage*

Age.	Total solids.[a]	Acid in total solids.		Ratio of nonvolatile to volatile.
		Nonvolatile.[b]	Volatile.[c]	
Weeks.	*Per cent.*	*Per cent.*	*Per cent.*	
3/7	28.9	Trace	0.51	.....
1	35.5	0.16	.87	1 : 5.40
2	26.7	.95	1.36	1 : 1.43
3	26.8	1.36	1.41	1 : 1.04
4	27.1	1.54	1.49	1 : .97
5	29.7	1.51	1.55	1 : 1.02
6	31.2	2.00	1.69	1 : .85
8	27.5	2.53	1.92	1 : .75
10	32.1	2.64	1.82	1 : .75
12	25.8	3.15	2.24	1 : .71

[a] Air-dried. [b] Calculated as lactic acid. [c] Calculated as acetic acid.

It is seen from the figures in Table I that for the first week the volatile acidity was greatly in excess if the nonvolatile portion; that from the second to the fifth week the two were apparently present in about equal amounts; and that from the sixth week on, the nonvolatile acids were in excess, the proportion of nonvolatile acidity increasing to the end of the experiment. The total acidity obtained was somewhat lower than is usually found in ordinary silage. This is probably to be expected, in view of the chemical differences in the raw materials. In this connection, however, it should be noted that in this experiment samples were not taken after the twelfth week. It is not unlikely that the acidity increased some after the last sample was secured. In regard to the proportion of nonvolatile to volatile acids, if we accept the ratio 1 to 0.75 reported by Dox and Neidig (*5*)[1] as representing a general average for ordinary silage, it will be seen that our results on corn stover silage indicate a remarkable agreement in this respect between these two types of ensilage.

FERMENTATION TEMPERATURES.—Temperature records were obtained by means of four resistance bulbs with about 60 feet of insulated cable attached to each which were buried in the silage as the silo was filled. The bulbs were located as follows:

No. 1. About 2 feet from the bottom and in the center of the silo.

No. 2. About 6 feet from the bottom and about 3 feet from the center of the silo.

No. 3. At the same height as No. 2 but about 3 feet from the center in the opposite direction.

No. 4. About 12 feet from the bottom and in the center of the silo.

The ends of the cables were located at a convenient place on the outside of the silo so as to allow easy attachment for temperature readings. Table II gives the temperatures obtained from April 4, the day the silo was filled, until June 16.

[1] Reference is made by number (italic) to "Literature cited," p. 600.

TABLE II.—*Fermentation temperatures of stover silage*

Date.	Temperature (°F.).				
	Bulb 1.	Bulb 2.	Bulb 3.	Bulb 4.	Atmosphere.
Apr. 4	42.0	42.0	42.0	.....	33.5
5	42.5	49.5	47.0	.....	42.0
6	46.5	50.5	48.0	46.5	43.0
7	46.5	51.0	48.5	47.5	46.5
8	47.0	52.5	49.5	48.0	33.0
9	47.5	54.0	51.0	49.5	33.0
10	49.0	54.0	51.0	50.5	37.0
11	49.0	54.5	51.5	51.0	42.0
12	49.5	54 5	52.0	52.5	48.0
13	50.0	56.0	52.5	52.5	58.0
14	50.5	56.0	53.5	55.0	51.0
15	50.0	56.0	53.5	55.0	49.0
16	50.0	56.0	53.5	55.0	50.0
17	50.0	56.0	53.5	55.5	52.0
18	50.0	56.5	54.0	56.0	49.5
19	50.0	57.0	54.5	56.0	46.0
20	50.0	57.0	54.5	56.0	55.0
21	50.0	57.0	54.5	55.0	49.5
22	49.5	57.0	54.5	56.0	49.5
23	49.5	57.5	55.0	57.0	41.5
24	50.0	57.5	55.0	57.0	47.0
25	50.0	57.5	55.0	57.0	47.0
26	49.5	57.5	55.0	57.5	48.5
27	49.5	57.5	55.0	57.5	48.5
28	50.0	57.5	55.5	57.5	47.0
May 1	49.5	57.0	55.5	58.5	66.5
2	49.0	57.5	55.5	59.5	63.5
4	50.0	58.5	56.5	59.5	53.5
6	50.0	58.5	56.5	59.5	60.5
8	50.0	58.0	56.0	59.0	65.5
16	50.5	58.0	56.0	59.0	65.0
22	50.5	58.0	56.5	59.0	55.0
31	51.0	58.0	57.0	61.0	64.0
June 16	52.0	58.5	57.5	63.0	63.5

Recent investigations have furnished abundant proof that high temperatures are not essential in silage preservation, and, in fact, do not occur except at the surface, which undergoes an aerobic decomposition. Bechdel (*3*) has recorded an instance in which the maximum temperature attained in the center of a concrete silo during the curing period was only 60° F. As has been shown by Eckles, Oshel, and Magruder (*6*), the atmospheric temperature at time of filling influences greatly the temperature attained during the fermentation of the silage.

Table II shows that the temperature at the start was 42° F. and gradually increased until the readings were discontinued. The maximum temperature attained was 63° F. in the case of bulb 4; but bulb 1, which was buried to a depth slightly below the surface of the surrounding soil, showed a maximum temperature of only 52° F. An examination of the column giving the atmospheric temperature during this period suggests that the continued increase in the silage temperature during the latter part of the time may be accounted for by a similar increase in

the outside air. However, the more rapid increase during the early part of the period was entirely independent of this factor. A comparison of the temperature records secured in this experiment with the data which have been obtained on ordinary silage at this and other Experiment Stations indicates that there is no wide difference, if any, between the rate and amount of increase in temperature in silos in which ordinary silage and corn-stover silage have been stored.

BACTERIOLOGICAL OBSERVATIONS.—A quantitative bacterial examination was made on each of the samples taken. The juice obtained was plated in proper dilutions and the counts obtained were reported as numbers per cubic centimeter of juice. Lactose agar was used, and the plates were counted after six days' incubation at 33° C. As may be seen from Table III, it appears that the bacterial count increases during the first week and is followed by a continued decrease thereafter.

TABLE III.—*Number of bacteria in stover silage at different stages of curing*

Age.	Number of bacteria per cubic centimeter.	Age.	Number of bacteria per cubic centimeter.
Weeks.		*Weeks.*	
3/7	528, 000, 000	5	510, 000, 000
1	3, 630, 000, 000	6	235, 000, 000
2	1, 850, 000, 000	8	186, 000, 000
3	975, 000, 000	10	98, 000, 000
4	400, 000, 000	12	71, 000, 000

Direct microscopic examinations of the silage juice were made in order to follow in a general way any marked changes which take place in the bacterial flora during the curing process. This at best could only give suggestive data, but such examinations are sometimes important in connection with cultural studies. At first a great variety of cells were observed. During the first two weeks rods and cocci were apparently present in about equal numbers, after which the rods became increasingly predominant. Toward the end of the experiment practically nothing but rods were found in the microscopic preparations. Because of the high acidity it is not likely that the cocci were active nearly as long as they appeared under the microscope. But it is probable that the acid medium would tend to peserve the cells so that they would appear for some time after they were inactive or even dead.

A qualitative bacterial study was also carried out. All of the colonies from a representative lactose-agar plate from each sample were isolated and subjected to a cultural study. For the present purpose they may be divided roughly, according to their action on litmus milk, into acid-forming, casein-digesting, alkali-forming, and inert groups. The acid formers may be further divided according to whether they produced sufficient acid to cause coagulation of the milk. The distribution of these groups in silage at various stages of its fermentation is shown in Table IV.

TABLE IV.—*Groups of bacteria present at different stages of curing*

Age.	Percentage of total number.				
	Acid-coagulating group.	Acid-noncoagulating group.	Casein-digesting group.	Alkali-forming group.	Inert group.
Weeks.					
3/7	10	53	10	4	23
1	14	57	9	6	14
2	20	71	0	0	9
3	11	63	5	0	21
5	21	67	0	0	12
6	60	30	0	0	10
8	68	32	0	0	0
10	60	40	0	0	0
12	56	39	5	0	0

Table IV shows that the rather complex bacterial flora which is present at the beginning of the process gives way to one which is almost entirely acid-producing as the fermentation progresses. The proportion of acid-forming and coagulating organisms to the noncoagulating ones also increases as the curing period advances. A comparison of these figures with those given in Table III indicates that the change in flora is not to be accounted for by an actual increase in the high acid-forming organisms during the latter part of the fermentation period, but rather to the fact that they do not decrease as rapidly because of their greater resistance to the unfavorable hydrogen-ion concentration.

The division of the acid-forming organisms into coagulating and noncoagulating types, though convenient and significant for the present purpose, probably does not separate them into natural groups. From early in the fermentation the predominating organisms were acid formers, most of which probably belonged to the same general group. We have found cultures which were apparently identical, as indicated by the cultural and fermentative reactions studied, but which varied in the amount of lactic acid produced in milk from only 0.3 to more than 2.0 per cent. All of these probably belonged to the same general group as the aciduric bacteria which have previously been noted as occurring abundantly in silage. In the first two samples examined organisms of the colon-aerogenes group were found and also a few cultures which were probably *Streptococcus lacticus*, but tests were not applied which would definitely identify the latter.

NATURE OF SILAGE FERMENTATION

Until recently the cell-respiration theory of silage fermentation established by Babcock and Russell (*1*, *2*) has not been seriously challenged. During the past year, however, several publications have appeared in support of the bacterial explanation of this phenomenon. In view of the recent contributions to the subject, it is not out of place to examine

critically the present status of the question. As the older literature has been reviewed so many times that further elaboration is not necessary, we shall pass in review only those papers of very recent date.

Hunter and Bushnell (*8*) have demonstrated the presence in silage of large numbers of high acid-producing bacteria, and have furnished strong evidence that these organisms are mainly responsible for the acid fermentation. Although their work is a most valuable one, it should be borne in mind that the evidence is circumstantial and perhaps not conclusive. It is rather doubtful if the data submitted justify the positive conclusion that—

> The present investigation warrants the statement that acid production, common to all normal silage, is largely the result of fermentation by the Bulgarian group of bacteria.

The fact that these bacteria formed considerable acetic acid when grown in alfalfa extract to which was added 1 per cent of glucose hardly warrants the assumption that—

> Although these organisms evidently do not produce all of the acetic acid found in normal silage, they must be responsible for a large per cent of it.

Sherman (*13*) also noted the presence of large numbers of the aciduric bacilli in silage and reported some observations which indicated that they are of significance in the fermentation process. The evidence, however, was not direct and by no means conclusive.

Hunter (*7*) in his work on heat production in silage has added further weight to the bacterial theory of silage fermentation. Unfortunately it is not possible to evaluate properly some of the interesting points contained in his paper, as they are obscured by insufficient description. For example, some data are given which show the difference in heat formation between green kafir heated and green kafir inoculated with *Bacillus bulgaricus*. The exact treatment in this case is not clear: If the inoculation was made into heated kafir, the results are of utmost significance; if, on the other hand, as the caption of the graph would indicate (*see* 7, *fig.* 9), the inoculation was made into unheated kafir and that compared with heated kafir, the test contributes nothing to the solution of the moot question. In his assumption that cell respiration can play no part in the fermentation of silage made from dry forage, Hunter has arrived, we think, at conclusions which are, in part at least, erroneous.

In a very interesting paper Lamb (*9*) concludes that both factors are of importance, but that microorganisms play the larger part, especially in the production of acid. Following the suggestion of Rahn (*10*), he has attempted to determine the cause of the process by the rates of change in the fermentations studied. The course of the curve obtained when such data were plotted was interpreted as indicating whether the action was of bacterial or enzymic origin.

Although it is true that purified enzym preparations acting under favorable conditions give time curves which follow, with certain modifications, the law of mass action, while curves representing bacterial action take an entirely different course because of an increase in the active mass with the multiplication of the organisms, we are inclined to believe that Lamb has placed undue confidence in this method, especially when we consider the complexity of the material studied and the factors concerned. A few considerations will suffice to illustrate some of the possibilities of error in such a method. In the first place conditions in silage are not constant, but are undergoing continual change. For example, the temperature and acidity, which are of utmost significance in enzym action, increase as the fermentation progresses. In view of the great increase in activity of some enzyms as the temperature is increased, and the stimulating effect on some enzyms of an increased hydrogen-ion concentration (within certain limits), it is not at all impossible that these factors might so modify the course of action of an enzym as to produce a curve resembling that typical of bacterial action.

Again, the phenomenon of adsorption and the action of the so-called antienzyms in many cases may so suppress the activities of an enzym during the early stages of the reaction as to cause it to follow a course not at all characteristic of enzym action. This has been beautifully illustrated by Rosenthal (*11*) in his work on the antitryptic action of egg albumen. It was shown that the trypsin was at first suppressed, but gradually regained its power and increased in activity so as to give the appearance of an increase in the "active mass" as indicated by a curve convex to the axis of abscissæ (the typical bacterial curve). On the other hand, the same trypsin preparation when acting on egg albumen which had been previously heated to destroy the antitrypsin gave a time curve characteristic of enzym action.

These illustrations will suffice to show the fallacy of such a method, but the number of possibilities of error in its application to such a complex mixture as silage might be increased almost indefinitely. That the limitations of this method of studying biochemical phenomena were appreciated by Rahn (*10*) is shown in the following paragraph from his valuable paper:

> It is hardly necessary to mention that the curve of a process will be an absolute means of discussion only in case of pure cultures. In natural fermentations, there is always the possibility that different processes taking place at the same time destroy the regular form of the curve. A simple example would be the growth of an acid-producing and an alkali-producing organism in the same liquid. It is also possible that an enzymic curve under certain conditions shows the form of a fermentation curve. We can imagine that an enzym is acting slowly at first, because of an unsatisfactory acidity of the medium. By a chemical or microbial process, independent of the enzymic action, the acidity may be made more suitable for the enzyme, and this will cause an increased rate of action of the enzyme and give the type

of a fermentation curve without the presence of organisms. The value of the curve is, therefore, not an absolute one and no conclusions ought to be drawn without consideration of the possibilities of error.

It would indeed seem that the application of such methods to the study of silage fermentation is entirely without foundation.

To the evidence in support of the bacterial theory of silage fermentation should be added the very suggestive observation of Clark (*4*) that the hydrogen-ion concentration of mature silage is coincident with the limiting hydrogen-ion concentration obtained in cultures of *Bacillus bulgaricus*, which organisms are considered by some workers as of paramount importance in the ripening process. In support of the respiration theory, on the other hand, it is pertinent to call attention to the recent work of Round (*12*), which indicates that cell respiration is of greater importance in the fermentation of sauerkraut than has been generally recognized.

It was thought at the beginning of this experiment that a study of the fermentation in silage made from dry stover would throw much light on the nature of the process in ordinary silage. The belief was held that the activity of the plant cells (which have been demonstrated to play an important part in the fermentation of silage made from green corn) would be eliminated, to a large extent at least, in the stover silage. But, as may be seen from an examination of the foregoing results, the fermentation of ensiled stover appears to resemble, in its main characteristics, that which takes place in green-corn silage. In an effort to determine the factors responsible for the fermentation, laboratory tests were made by ensiling stover under different conditions. Glass jars containing 175 gm. of cut stover and 400 gm. of water were used. Some were untreated, some put up with antiseptics, while some were sterilized in the autoclave and reinoculated with 1 per cent of raw-silage juice. The results of this study are given in Table V.

TABLE V.—*Fermentation of stover ensiled under different conditions*

Sample No.	Treatment.	Age.	Acidity.	Bacterial count.
		Weeks.	*Per cent.*	
1	Untreated	4	15.5	210,000,000
2	....do	4	10.4	240,000,000
3	Sterilized and inoculated	7	2.4	320,000,000
4	....do	5	3.3	36,000,000
5	2 per cent of toluene	6	4.3	180,000
6	....do	6	4.6	460,000
7	2 per cent of ether	5	10.8	7,500,000
8	....do	8	12.4	Not made.

The main points brought out by this test are that stover silage is capable of undergoing a fermentation when preserved with ether, while bacteria alone are apparently unable to produce the typical fermentation, even though conditions are favorable for their active development. The predominating organisms in the sterilized and inoculated samples

were of the same type as those characteristic of normal silage. The organisms found in the samples preserved with antiseptics, on the other hand, were a more miscellaneous group; and, although many probably belonged to the same group as the aciduric bacilli of normal silage, the cultures isolated were mostly very weak acid producers. The fact that fermentation took place under ether indicates that the activity of the plant cells, whether it be called "respiration" or "autolysis," is present in silage made from dry stover. As silage preserved with ether fermented, whereas in that kept with toluene the process was checked suggests that conclusions drawn from experiments conducted with only one antiseptic are of doubtful value. When opened, the ether-preserved samples, after the evaporation of the ether, appeared to resemble the untreated material, while the sterilized and inoculated silage were "flat" and lacking in the characteristic aroma. The results with ether were checked by another test in which triplicate samples were preserved, and again an active fermentation took place as was indicated by the development of acidity in each case.

Although our results would tend to support the respiration theory of silage-curing rather than the bacterial, we do not feel that the data thus far collected warrant definite conclusions on this point. It is difficult to believe that such active acid-forming organisms should occur in silage in large numbers without taking some part in the acid fermentation; perhaps they supplement in some important way the action of the plant cells. It is not inconceivable that a preliminary cleavage due to cell respiration is an essential prerequisite for the vigorous action of the aciduric bacteria. In fact, the continued increase in the ratio of nonvolatile to volatile acidity as the fermentation progressed (see Table I) might lead one to suspect that such was the case. On the other hand, the great increase in the nonvolatile acidity from the fifth to the twelfth week, during which time the bacterial count was rapidly decreasing, might be interpreted as strong evidence against that view. It is clear that microorganisms are not solely responsible for the fermentation of silage, and the weight of evidence at the present time, in our opinion, indicates that their rôle is not as important as that of the plant cells.

Although not committing ourselves definitely on the nature of silage fermentation in general, in regard to the present problem we do maintain that the fermentation which takes place in stover silage is similar in its essential points to that of ordinary silage and is caused by similar factors.

SUMMARY

Corn stover when ensiled with a suitable quantity of water undergoes fermentation with the production of a palatable silage of good keeping quality, which resembles ordinary corn silage in aroma and appearance.

The fermentation which takes place in corn-stover silage appears to be essentially the same as that of silage made from green corn, as is

indicated by the total acidity developed, the ratio of nonvolatile to volatile acids, temperature observations, and bacterial studies.

From a review of the present status of the question as to whether bacteria or plant cells are mainly responsible for silage fermentation, it is concluded that the data thus far published are inconclusive. Although the results of the present study tend to support the cell-respiration theory, conclusions on this point are withheld.

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WEEVILS WHICH AFFECT IRISH POTATO, SWEET POTATO, AND YAM

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INTRODUCTION

In a previous article [1] the writer discussed three important Andean weevil pests of the potato tuber (*Solanum tuberosum*). In the present paper a fourth potato tuber weevil is described and notes are presented on three weevils which attack the tubers of sweet potato (*Ipomoea batatas*) and one which attacks the tubers of the yam (*Dioscorea batatas*).

WEEVILS WHICH AFFECT IRISH POTATO TUBERS

The native home of the Irish potato is the west coast of South America, and here we find that the crop has a series of characteristic pests which may be easily disseminated in shipments of potatoes. As stated above, the writer has described three of these species in a previous paper. The description of the larva of one of them is now added and a new species described. In order that these weevils may be easily distinguished one from another by the man in the field the following table has been constructed:

TABLE OF IRISH POTATO TUBER WEEVILS

1. Prosternum grooved for reception of beak; mandibles without deciduous piece; pronotum with a deep median furrow widened angularly at middle and also behind..... *Rhigopsidius tucumanus* Heller.
   Prosternum not grooved for reception of beak; mandibles with deciduous piece.. 2
2. Mandibles with tooth beneath; scrobes abruptly and broadly terminated, not extending beneath..... 3
   Mandibles without tooth beneath; scrobes narrowing and extending beneath; prothorax not as wide as elytra, angulate and broadest in front of base..... *Premnotrypes solani* Pierce.
3. Prothorax broader than elytra, subquadrate, with sides parallel to apical third, thence strongly narrowed; sides of elytra smooth.. *Trypopremnon latithorax* Pierce.
   Prothorax acutely angulate at sides, widest before base; sides of elytra tuberculate, *Trypopremnon sanfordi*, n. sp.

[1] Pierce, W. D. New potato weevils from Andean South America. *In* Jour. Agr. Research, v. 1, no. 4, p. 347-352, 3 fig., pl. 39-41. 1914.

FAMILY PSALIDURIDAE PIERCE (1914)

Rhigopsidius tucumanus Heller (1906)

This weevil has been recorded by the writer [1] from Tucuman, Argentina; Cuzco, Temuco, and Arequipa, Peru; Oruro, Bolivia; and Ancud or San Carlos and Castro Islands, Chile. The weevil belongs to the subfamily Rhytirhininae and the tribe Rhytirhinini.

FAMILY PSALLIDIIDAE PIERCE (1916)

Premnotrypes solani Pierce (1914) [1]

This weevil was described from the mountain districts of Peru. It belongs to the subfamily Entiminae and the tribe Ophryastini.

Trypopremnon latithorax Pierce (1914) [1] (Pl. 29, 30)

This weevil was described from Cuzco, Peru. It belongs to the same tribe as Premnotrypes. The ventral tooth of the mandible does not belong to the deciduous piece as stated in the original description.

On June 11, 1914, Mr. H. L. Sanford found several larvæ of this species in potatoes from La Paz, Bolivia, collected by Mr. H. T. Knowles, under Federal Horticultural Board No. 2475. On June 20–26 pupæ were noticed, and an adult emerged on June 26.

This enables the writer to describe these stages.

LARVA (Pl. 29).—Length 12.5 mm. when crawling, 10 mm. when slightly curved. It is typically rhynchophorid in form, white, with light reddish brown head and dark mandibles. The essential diagnostic characters are illustrated by the author in Plate 29.

From the base of the head a median pale line passes forward. This is the epicranial suture. It divides behind the frons and forms the two frontal sutures. The frons is subtriangular, rounded behind and margined in front by the epistoma. The epicranial areas are the two large areas at each side of the epicranial suture, further bounded by the frontal suture, the pleurostoma, and the hypostoma. In front of the frons is the clypeus, and in front of this is the labrum. The clypeus and labrum partly overlap the mandibles which arise at the side of the clypeus based on the pleurostoma. Below the hypostoma at the sides of the mandibles arise the maxillæ, of which the cardo is a very large basal area. Located on the median line below the mouth opening, which is covered by labrum and mandibles, is a shield-shaped area known as *stipes labii*. Below and around this is the large basal area consisting of mentum and submentum.

There is a small abortive branch of the frontal suture extending back on the epicranium, on each side of and not far from the epicranial suture. It is terminated by a setigerous puncture. On the epicranium there are setæ arranged as follows on each lobe: One at terminus of branch of frontal suture, one on the frontal suture, two opposite middle of frons, one basal, two discal, one opposite base of mandible, two on hypostoma. On the frons there are three pairs of setæ, the two posterior pairs being about equidistant, the anterior close to the antennæ. At base of clypeus there are four tiny hairs. On labrum are four subbasal, six subapical, and six marginal hairs. The mandibles have one hair each. The maxillæ are provided with two-jointed palpi (Pl. 29, F), and a very broad setose lacinia, two setæ near base of palpi and one near base. Some of the hairs are clavate as shown in the illustration, but this is not always true, some specimens having normal hairs. The *stipes labii* has one pair of hairs. Each lobe of the mentum has one pair.

[1] PIERCE, W. D. Op. cit.

The pronotum is simple, undivided; the mesonotum and metanotum are composed of præscutum and scutoscutellum. The first six abdominal sclerites are composed of a spindle-shaped præscutum, a transverse scutum terminated by the spiracles, a spindle-shaped scutellum, and a transverse postscutellum very greatly narrowed on the dorsum. The præscutum has a few hairs. The scutellum has a row of hairs. Just above each spiracle is a tiny hair. On each epipleural lobe beneath the spiracles there is one hair. There are eight abdominal spiracles and one on the mesothorax. The seventh and eighth segments are more crowded than the preceding. The ninth and tenth are small and reduced.

PUPA (Pl. 30).—Length 10 mm., white. The most interesting features of this pupa are the rudimentary wing pads seen only when the elytra are spread. The elytral pads are not as large as often found in weevil pupæ. The antennæ are not geniculate. The beak is short. There are five pairs of hairs located on the head and beak as illustrated. On the thorax, which is subquadrate with truncate angles, there are setigerous tubercles as follows: Four on anterior margin, two antemedian and two postmedian on the disc, two pairs of antemedian and two pairs of postmedian on lateral margin. Mesonotum and metanotum with one pair of setæ each. The first abdominal segment has two pairs of setæ, and the remaining segments have a long line of setigerous tubercles. Each femur has two apical hairs, and a few ventral hairs are found as illustrated. It is interesting to note that the processes of the ninth segment are acute but reduced almost to the size of the tubercles. The tenth segment is ventral to the ninth.

Trypopremnon sanfordi, n. sp. (Pl. 28)

Described from a single specimen collected in quarantine by Mr. H. L. Sanford September 24, 1915, from a potato tuber sent by Mr. O. F. Cook from Cuzco, Peru.[1] The excellent illustrations of the type (Pl. 28) were made under the writer's supervision by Mr. H. B. Bradford.

Length 8 mm., greatest breadth 4.5 mm. Beak longer than head and narrower than eyes; the dorsal squamose portion being gradually narrowed from eyes to nasal plate. Alæ strongly flared, making the scrobes open above. Head tumid above the eyes. Median line slightly depressed on head, strongly in frontal fovea, and very faintly on beak except just behind nasal plate. Lateral depressions on beak strong. Apex of beak brownish black, with nasal plate polished, convexly raised around margin, emarginate at apex. Mandibles shining brownish black; deciduous piece reddish brown, lightest at tip, moderately long, arcuate, with sharp edges; the ventral tooth is not as acute as in *T. latithorax*; there is a slight denticle on the right deciduous piece, and the left mandible is denticulate as shown in the figure. The antennal scrobes are strongly flexed downward, very much broadened and evanescent behind; scape clavate; funicle with first two joints elongate, the others progressively shorter, the last moniliform; club as long as the four preceding joints. Head, beak, and scape densely clothed with fine silky-bronze scales, and with scattered white setæ; funicle sparsely setose; club minutely pubescent, sparsely setose.

Prothorax basally truncate, slightly broadly emarginate at middle; apically sinuate; with very strong supraocular lobes, which have vibrissæ on the inner surface; surface coarsely irregularly punctured, finely densely squamose with golden metallic scales, sparsely setose with white curved setæ; surface very uneven, with median depression bordered by antemedian ridges and two postmedian tubercles; sides prominently produced by two angulate tubercles; widest at posterior tubercles.

Elytra at base narrower than thorax; humeri tuberculate; sides subparallel but very roughly tuberculate, abruptly narrowed at posterior declivity which is nearly perpendicular. Scutellum triangular. Surface densely minutely squamose, sparsely

[1] Recorded under Federal Horticultural Board No. 4348.

setose; striæ irregular, with strong isolated punctures; entire surface covered with tubercles which are largest on the third, fifth, and seventh intervals.

Front coxæ contiguous. Prosternum strongly arcuately emarginate. Mesosternal coxæ narrowly separated. Intercoxal piece of first abdominal segment broad and deeply punctate. Second segment as long as third and fourth together.

Type.—Cat. No. 21613, United States National Museum.

WEEVILS WHICH AFFECT SWEET-POTATO TUBERS

At least four species of weevils attack the tubers of the sweet potato—namely, *Euscepes batatae* Waterhouse, *Cylas formicarius* Fabricius, *C. turcipennis* Boheman, and *C. femoralis* Faust. The adults of Euscepes and Cylas can not be confused. Those of Cylas are differentiated as shown in the "Table of sweet-potato weevils of the genus Cylas," p. 605. The pupæ of Cylas can be recognized from the fact that the direction of the appendages is anteriad, while in Euscepes it is posteriad. Reference to the illustrations will be of great assistance in separating them. The larvæ can not be so easily distinguished, as both are of the same general shape. It will be noticed, however, that they have quite a different system of abdominal folds. The larva of Euscepes is more compact. That of Cylas, when alive, is often attenuate and tightly drawn so that no folds can be distinguished. When killed in a liquid which shrinks it slightly, however, it will be noticed that the præscutal areas are proportionately larger and often subdivided transversely. The præscutum of Euscepes is not subdivided. This sclerite is the anterior sclerite of a segment and almost always has a few tiny hairs. The only other dorsal sclerite with hairs is the scutellum. In Cylas the scutellum adjoins the præscutum, and the scutum is only lateral. In Euscepes the scutellum is separated from the præscutum by the scutum.

FAMILY APIONIDAE LE CONTE (1876)

SUBFAMILY CYLADINAE PIERCE (1916)

GENUS CYLAS LATREILLE (1802)

Cylas Latreille, 1802, Hist. Nat. Gen. et Part. Crust. et Insects, t. 3, p. 196.

Type.—*Cylas brunneus* Fabricius, monotypic.

This genus contains twenty named species, of which two are widely known under the names *formicarius* and *turcipennis*. There is considerable confusion about these two species, due in part to the claims of Le Conte and Faust that they are synonymous. Fabricius described a piceous-brown Indian species with reddish thorax as *formicarius;* Olivier illustrated the species as almost pink but described it as brownish; Schönherr cited it as piceous; Gyllenhal described a species from Java with greenish-blue elytra, red thorax, and black head as *turcipennis;* Labram and Imhoff illustrated a blue species under this name. Finally Wagner presented an illustration of a species with green elytron as *turcipennis*, and he probably is right. The bluish species was named *elegantulus* by Summers. It is a common sweet-potato weevil. If it

should prove to be a variety of *formicarius* as here treated, after examination of the type, it must still be considered very distinct specifically from *turcipennis*. The National Museum collection contains six species. Sketches have been made of the side view of the head and thorax of the three species which presumably attack sweet potato, *formicarius* variety *elegantulus* (Pl. 31, A), *femoralis* (Pl. 31, F), and *turcipennis* (Pl. 31, B), and also of *brunneus* (Pl. 31, C–E), which was erroneously recorded by the writer from sweet potato in the Manual of Dangerous Insects.[1]

TABLE OF SWEET POTATO WEEVILS OF THE GENUS CYLAS

1. Male club twice as long as funicle or longer; antennæ as long as head and thorax; head not more than one-fifth shorter than beak; elytra greenish, thorax red, head black, legs red with dark band (Pl. 31, B)..... *turcipennis* Boheman.
   Male club not twice as long as funicle 2
2. Male club half to three-fourths longer than funicle, female club almost one-third shorter than funicle; male antennæ almost as long as head and thorax; head one-fourth to one-third shorter than beak; elytra bluish, thorax red, head black, legs red (Pl. 31, A)..... *formicarius* Fabricius, var. *elegantulus* Summers.
   Male club half longer than funicle; head as long as beak; antennæ as long as thorax plus head behind eye; elytra black with blue or green luster, suture piceous; thorax black, margins piceous; head black; legs dark red with black ring on femora (Pl. 31, F)..... *femoralis* Faust.

Cylas formicarius Fabricius (1798)

Brentus formicarius Fabricius, 1798, Sup. Ent. Syst., p. 174, no. 5.

Fabricius[2] gave the following description:

Habitat Tranquebariae.

Parvus in hoc genere. Rostrum cylindricum, atrum, antennis rufis, moniliformibus: articulo ultimo longiori, cylindrico, clavato. Thorax rufus, antice globosus. Elytra laevia, atra, nitida. Pedes rufi, femoribus clavatis, at inermibus: annulo nigro.

In altero sexu antennarum clava brevior, ovata.

Olivier and Schönherr described the species as piceous with ferruginous thorax, antennæ, and legs. It hardly seems possible that this can be the same species as the common sweet potato weevil with shiny blue-black elytra, red thorax and appendages, and black head and beak.

For this reason it is considered best to apply to the sweet-potato weevil a name which certainly applies to it—*elegantulus* Summers. In order that economic entomologists may not be inconvenienced greatly, and in deference to the many writers who have assigned Fabricius's name to the sweet-potato weevil, *elegantulus* may be considered as a variety of *formicarius* until there can be an examination of the type.

Cylas formicarius elegantulus Summers (1875), the Sweet Potato Weevil (Pl. 31, A; Pl. 32, A, B; Pl. 33, E–H; Pl. 34, A–D)

Otidocephalus elegantulus Summers, 1875, *in* New Orleans Home Jour., Jan. and Dec.

Cylas formicarius Le Conte, 1876, *in* Proc. Amer. Phil. Soc., v. 15, p. 327. *O. elegantulus* is quoted in synonymy.

[1] PIERCE, W. D. A MANUAL OF DANGEROUS INSECTS ... p. 209. 1917. Published by the United States Department of Agriculture, Office of Secretary.

[2] FABRICIUS, J. C. SYSTEMA ELEUTHERATORUM ... v. 2, p. 549. Kiliae, 1801.

This is the common sweet-potato weevil (Pl. 31, A; 32, A, B) with bluish elytra, red thorax and appendages, and black head. The illustration of the adult is drawn from a New Orleans specimen. The side view of head and thorax is from a Hawaiian specimen. There is quite a range of difference in measurements of the species but the analysis of these differences is reserved for a more technical paper now in preparation. The immature stages are described from specimens collected at Victoria, Texas.

LARVA. (Pl. 34, A–D).—The larva of this species measures from 5 to 8 mm. in length and is white, with light brownish head and darker brown mandibles. The head shield is slightly angulately emarginate behind. From the center of the emargination on the median line the epicranial suture passes forward, separating the epicranium into two parts; this suture divides behind the frons and forms the two frontal sutures. The frons is subtriangular, emarginate at anterior angles for antennæ, and emarginate along epistoma for attachment of clypeus. The median line is impressed and darkened. The frons has three pairs of large setæ, the posterior pair being closest and the median pair but little more separated. The anterior pair are located very close to the antennal fossæ. A tiny pair of setæ are located in such a way as almost to form an equilateral triangle with the posterior and median setæ.

The epicranial areas are located on each side of the epicranial suture. Each lobe bears the following setæ: One very close to the apex of frons, one slightly posterior to this and farther from the median line, one opposite the middle of the frons, one a little farther from the median line on the same line as the preceding, one toward the base of the frons, one opposite the middle of the mandible, one opposite the hypostomal angle of mandible, one on hypostoma near base of mandible, one opposite but distant from mandible, and three forming a triangle on disc of epicranium.

The antenna is a fleshy, two-jointed appendage located at the lateral angle of the frons. The mandibles are very bluntly bidentate. Each mandible has a tiny hair about the middle. The clypeus is attached in front of the frons and is broadly transverse. It bears on the epistomal margin four tiny hairs. The labrum is not as broad, is rounded in front, and has a row of four setæ behind the middle, a seta on each side in front and closer than the outermost setæ, and four marginal setæ. The maxillæ are elongate, terminated by a two-jointed palpus and a setose lacinia. The maxillæ are provided with four setæ, two near palpus, one at middle, and one at base. The *stipes labii* is cordate, bearing two-jointed palpi and a single pair of setæ. Each lobe of the mentum is provided with two pairs of setæ.

The entire surface of the body is covered with tiny pubescence.

The prothorax is dorsally not divided but has the præscutal and scutal areas indicated by rows of setæ. The mesothoracic spiracle is located on a lobe very close to the prothorax. The præscutum of the prothorax and that of the mesothorax are provided with a few small hairs. The scutellum is marked with a row of hairs.

The first eight abdominal segments are normal and each bears a spiracle. The præscutal area is more or less transversely divided, and its posterior lobe is marked with a few tiny setæ. The scutellum is large and prominent and provided with a row of setæ. The scutum is only lateral and has just above the spiracle a tiny seta. Each epipleural lobe is provided with a single seta, and each hypopleural lobe with two setæ. The coxal lobes of the thorax bear several setæ, and those of the abdomen a single seta each. The last two abdominal segments are simple and provided with a number of setæ.

PUPA (Pl. 33, E–H). Elongate, about 6 mm. long, white. This pupa is especially characterized by the nongeniculate antennæ which lie parallel to the legs. The antennæ and two anterior pairs of legs are directed cephalad instead of posteriad,

as in the Curculionidae. Another characteristic is that the femora and tibiæ of the posterior pair, being directed in the same manner, are completely covered by the wings. The head and beak are elongate and provided with setigerous tubercles as follows: One pair between the eyes at base, one pair immediately behind eyes, two tiny pairs between eyes, and two pairs on beak; the posterior pair being close to the eyes, and the anterior behind the middle. The antennæ are roughly tuberculate.

The prothorax is margined anteriorly by four pairs of setigerous tubercles and has one pair of discal setæ. The mesothorax has two pairs of large setigerous tubercles and a lateral pair of tiny setæ. The femora bear two or three setæ. The knees of the posterior femora are visible dorsally only.

The mesothorax bears three pairs of small setæ between the bases of the elytra. The metathorax is provided with two rows of setæ on tiny tubercles, the anterior row having two pairs and the posterior row six pairs. The abdominal segments have dorsally five pairs of setigerous tubercles near the posterior margin, a pair of tiny setæ near the middle of the segment, and lateral setigerous tubercles.

The ninth segment is provided with two large curved processes. The tenth segment is ventral to the ninth.

Cylas turcipennis Boheman (1833) (Pl. 31, B)

Cylas turcipennis Boheman, 1833, *in* Schönherr, Gen. et Spec. Curc. v. 1, p. 369-370.

The brief preliminary diagnosis of the species presented by Boheman is as follows:

Elongatus, viridi-cœrulescens, nitidus, antennis thorace pedibusque rufis, capite cruciatim impresso, rostro punctulato, elytris modice convexis, subtiliter striato-punctatis. Habitat in Java, in India orientali.

The following dimensions are included in the detailed description: Length 3 lines (6 mm.); antennæ as long as thorax and head; club of male antenna longer than preceding joints; beak not longer than head; elytra twice as wide as thorax at base, and twice longer than wide. The color description is as follows: Head obscurely viridi-cœruleous; beak almost black; antennæ rufo-ferruginous; thorax shining rufous; elytra cœrulescent-virescent; thorax beneath rufous, remainder of body beneath cœruleo-virescent; legs rufous; tarsi beneath fulvous, spongy; female with femora in middle annulate virescent.

Two specimens from Palembang, Sumatra, collected by Mr. M. Knappert, are here considered as this species. They differ only in having the beak slightly longer than the head, and a statement to this effect might have been made if the description had been based on examination with a low-power lens. Two other specimens are at hand from Bay Laguna Province, Philippine Islands, collected by Mr. P. L. Stangl. A part of a body of a weevil from Guatemala, collected by Mr. D. G. Eisen, is also undoubtedly this species. Pascoe records the species from Sarawak, Java, and India.

Cylas femoralis Faust (1898) (Pl. 31, F)

Cylas femoralis Faust, 1899, *in* Deut. Ent. Ztschr., p. 24.

This species was collected by Mr. Rolla P. Currie at Mount Coffee, Liberia, in February to April, 1897, and he has informed the writer that it was a serious sweet-potato pest in that country. It is described from Kamerun. In the Manual of Dangerous Insects [1] this species was referred to as *C. brunneus* by mistake.

[1] PIERCE, W. D. A MANUAL OF DANGEROUS INSECTS ... p. 209. 1917. Published by the United States Department of Agriculture, Office of Secretary.

FAMILY OROBITIDAE PIERCE (1916)

SUBFAMILY OROBITINAE PIERCE (1916)

GENUS EUSCEPES SCHÖNHERR (1844)

Euscepes Schönherr, 1844, Gen. et Spec. Curc., v. 8, pt. 1, p. 429. Type.—*porcellus* Boh. by original designation.

Euscepes Lacordaire, 1866, Gen. Coleop., v. 7, p. 100-101. Type.—*porcellus* Boh.

Hyperomorpha Blackburn, 1885, *in* Sci. Trans. Roy. Dublin Soc., s. 2, v. 3, p. 182-183. Type.—(*squamosa*, Blackburn)=*batatae* Waterhouse.

Euscepes Champion, 1905, *in* Biol. Centr.-Amer., Coleopt., v. 4, pt. 4, p. 496-498. Type.—*porcellus* Boh.

Lacordaire caused a confusion of genera by wrongly interpreting the number of funicular joints, of which there are seven. This error was corrected by Champion. The two genera Euscepes and Hyperomorpha are strictly congeneric; in fact, the two type species differ principally in size. A large series of *porcellus* from various parts of Central America is at hand. These have been carefully compared with Blackburn's description of Hyperomorpha, but no generic difference can be found.

The rostral canal extends along the prosternum and ends in a mesosternal pocket. The beak when at rest fits tightly into this canal. The prothorax is lobed to cover the eyes when at rest. The body is elongate.

Euscepes batatae C. O. Waterhouse (1849), the Scarabee of the Sweet Potato (Pl. 32, C, D; Pl. 33, A-D; Pl. 34, E-H)

Cryptorhynchus batatae Waterhouse, 1849, *in* Trans. Ent. Soc., London, v. 5, p. LXIX.

Hyperomorpha squamosa Blackburn, 1885, *in* Sci. Trans. Roy. Dublin Soc., s. 2, v. 3, p. 182-183.

Euscepes batatae Champion, 1905, *in* Biol. Centr.-Amer., Coleopt., v. 4, pt. 4, p. 497.

This weevil (Pl. 32, C, D) is one of the most serious cosmopolitan pests of the sweet potato, although hitherto it has been recorded only from Barbados, St. Vincent, and Antigua, St. Kitts, Nevis, and Hawaii. In all of these places, however, it is reported as damaging sweet potatoes. The receipt of two specimens from Dr. Da Costa Lima, of Brazil, with the statement that they were injuring sweet potatoes at Rio de Janeiro, caused the writer to make a search through the undetermined collections of the National Museum with the result that the known distribution of the species is hereby greatly extended. Specimens are at hand from Barbados, injuring sweet potatoes May 22, 1900, and more recent material; Hope, Kingston, Jamaica, on sweet potatoes, Mr. S. F. Ashby; Campinas, Brazil, injuring sweet potatoes, August, 1913, Mr. A. Hempel (No. 100); Rio de Janeiro, Brazil, injuring sweet potatoes, July, 1917, Carlos Moreira; Honolulu, Oahu, Hawaii, bred from sweet potato; Kaimuki, Oahu, Hawaii, bred from sweet potato; Guam, on sweet potato, Mr. D. T. Fullaway; Norfolk Island, New Zealand, March, 1883, Mr. P. H. Metcalfe; Mayaguez, Porto Rico, injuring sweet potatoes, 1912, 1914, 1917, Mr. C. W. Hooker, Mr. R. H. Van Zwaluwenburg.

This extensive distribution indicates that there are probably many other countries where sweet potatoes are grown that may have the weevil. If, fortunately, it should prove to be absent in other countries, rigid quarantines should be put into effect, such as that recently estab-

lished by the United States. In fact it has been only because of the excellent system of quarantine inspection in California that the species has not already come into the United States with Hawaiian potatoes. Many shipments of infested sweet potatoes have already been intercepted at the California ports.[1]

The following is a description of the species redrawn to include all the material at hand. The variations of color will be mentioned in subsequent paragraphs.

Length about 4 mm. Brown, mottled with lighter areas, especially by a transverse, irregular, postmedian band on the elytra. Squamose, bristling with upright setæ. Beak curved, carinate and laterally bifurcate. Front foveate. Front and beak bristling with erect scales. Vertex provided with more decumbent scales. Prothorax constricted in front, laterally impressed on disk behind, mottled with erect scales, except on posterior margin which is provided with smaller, more decumbent scales. Elytral striæ composed of rather distant punctures, each bearing a small scale; surface closely set with overlapping scales and each interspace with a single series of elongate squamiform setæ. Undersides more sparsely clad with semierect scales. Legs provided with scales and setæ. Rostral canal deep, terminating in a prominent pocket of the mesosternum. Intercoxal process broad, angulate on anterior margin. First segment behind coxæ subequal to the second, which is but slightly longer than the subequal third and fourth segments. The femora are minutely toothed.

Mr. Bradford's excellent illustrations will be very helpful in identifying this weevil. His illustration of the adult is from Hawaiian material.

The species varies from very light brown to almost black and on the darkest specimens the mottling and the postmedian vitta have practically disappeared.

On light specimens the scales of the thorax are mostly dark brown, with flecks of pale scales and with the basal scales orange colored. The scales of the elytra are mottled in many shades of brown. The postmedian fascia extends to the fifth interspace and is bordered by very dark scales and divided by a wavy dark line. The erect setæ are mixed dark and white. The ventral scales are pale, but on the legs they are mottled dark brown and pale. This description fits best some of the Jamaican, Barbados, and Brazilian specimens. Almost black material comes from Brazil, Jamaica, and Guam. The Hawaiian specimens are a duller brown, and the New Zealand material is the lightest of all. There is, however, no doubt of the specific identity of the entire series.

In order that the immature stages may be readily distinguished from those of *Cylas formicarius* a series of very careful drawings of the essential characters of the larva and pupa have been made by Mr. Harry Bradford under the writer's direction. The drawings of the vertex and face are by the writer. Barbados material was used for these drawings.

LARVA (Pl. 34, E–H). The larva of this species measures about 5 mm. in length and is white, with a yellowish head and reddish brown mandibles tipped with black. The maxillæ and labium are slightly tinged with brown.

The head shield is broadly, angulately emarginate behind; from the center of the emargination on the median line the epicranial suture passes forward, separating the epicranium into two parts. This suture divides behind the frons and forms the two

[1] WHITNEY, L. A. THE SMALL SWEET POTATO WEEVIL (CRYPTORHYNCHUS BATATAE WATERH.). *In* Mo Bul. State Com. Hort. [Cal.], v. 4, no. 3, p. 162-164, fig. 24-28. 1915.

frontal sutures. The frons is subtriangular, rounded at anterior angles, and slightly emarginate for antennæ; its front margin is the epistoma. There are three pairs of large setæ on the frons, the posterior pair being located rather close together and near the apex of the triangle. The second pair are farther apart and halfway to the front. The anterior pair are located near the lateral angles just behind the antennæ. A tiny pair of setæ are located just in front of the posterior pair of large setæ. A tiny pair are located slightly behind and outside of the median pair of large setæ. The median line of the frons is impressed from the posterior angle almost to the middle.

The epicranial areas are the two large areas on each side of the epicranial suture further bounded by the frontal suture, the pleurostoma, and the hypostoma. The following setæ occur on each lobe of the epicranium: One opposite the apex of the frons, one on the disk of the epicranium in the line with the preceding; one opposite the middle of the frons and near the frontal suture; one near the hypostoma toward the base of the mandible; one as close to the hypostoma and opposite the base of the maxilla; one near the pleurostoma; the last three forming a triangle. Forming a semicircular line with the setæ opposite the frons are a tiny seta, a longer one opposite the antenna, and a long one opposite the pleurostomal seta.

The antenna is a small, fleshy, two-jointed appendage at the angle of the frontal suture and pleurostoma. The mandibles are bluntly bidentate and have two small setæ. The clypeus is attached in front of the frons and is broadly transverse. It bears on the epistomal margin four tiny hairs. The labrum is not as broad; it has a pair of median setæ and three pairs of marginal setæ. The maxillæ attached at the side of the mandibles are terminated by a two-jointed palpus and a setose lacinia. The maxillæ are provided with three setæ, two near the palpi and one toward the base. The *stipes labii* is appendiculate, bilobed, bearing two-jointed palpi and a single pair of posterior setæ. Each lobe of the mentum is provided with one seta. The thoracic segments are simple, being composed of only præscutum and scutoscutellum. In the prothorax there is no separation of these parts, but they are indicated by the arrangement of the setæ. The abdominal segments are dorsally composed of four single sclerites, namely, præscutum, scutum, scutellum, and postscutellum.

The thoracic spiracle is located on a lobe of the mesothorax, very close to the head. The abdominal spiracles are located on a small lobe at the side of the scutum on the first eight segments. The ninth and tenth abdominal segments are smaller and considerably modified.

Setæ are arranged as follows: Four pairs of tiny hairs on anterior margin of prothoracic præscutal area; a row of longer hairs on the scutal area of the prothorax; each segment from the mesothorax back with two pairs of long lateral setæ, near which are located smaller and inconspicuous setæ; each præscutum with a single pair of setæ; on each segment of the abdomen the lateral lobe of the scutellum is provided with a tiny seta, behind and close to the spiracle; each epipleural lobe below the spiracle with two setæ; each coxal lobe with several setæ which are more conspicuous on the prothorax.

PUPA (Pl. 33, A–D).—Length 4 mm., white. This is a normal, characteristic curculionid pupa with geniculate antennæ and legs turned posteriad. Head oval, beak short. The head bears four pairs of basal setigerous tubercles, two pairs of interocular tubercles, and one pair of tiny setæ at base of beak. Prothorax with two pairs of antero-marginal setigerous tubercles; one pair of antero-lateral and one pair of postero-lateral setigerous tubercles; four pairs of dorsal tubercles and one pair of ventral. The femora are apically armed with two setæ. Mesonotum and metanotum each provided with two pairs of setæ. Each abdominal segment bears four dorsal and one or more lateral setæ. The ninth segment is armed with two very large processes. The tenth segment is very small and located on the venter of the ninth.

A WEEVIL WHICH ATTACKS THE TUBERS OF YAMS

Palaeopus dioscoreae, n. sp. (Pl. 32, E, F)

Described from two specimens reared from tubers of *Dioscorea batatas*, Hope, Kingston, Jamaica, by Mr. S. F. Ashby in April, 1914. Belongs in the same subfamily as Euscepes.

Length 4.5 mm., breadth 1.75 mm. Piceous black, with reddish brown appendages. It is sparsely clad with dark brown or whitish oblong decumbent scales and erect, longer truncate scales of variable color. The punctuation is very coarse.

Head smooth, beak separated from head by strong transverse constriction. Beak longitudinally five-striate and bristling in basal half with erect brown scales; apical half smoother, with confluent punctures and flat scales. Scrobes beginning beyond middle, diagonal, reaching eyes beneath. Eyes lateral, separated by width of beak, covered when at rest by pronotal lobes. Antennal funicle seven-jointed, first joint a little longer than second. Prothorax broad, depressed, convexly rounded on sides, bisinuate at base, lobed over eyes, truncate at apex which is about half as wide as base; median line broadly elevated; punctuation very coarse. Elytra 10-striate, the tenth striæ abbreviated; strial punctures large, rounded, well separated, and setigerous; interspaces not wider than striæ, clad with a single row of erect squamose setæ of variable color. Scutellum indistinct. Elytra broader at base than thorax; with distinct humeri.

Sternal canal deep, sharply margined, limited by a cuplike depression of the mesosternum. Posterior coxæ very broadly separated. Metasternum at middle as long as first abdominal segment behind coxæ. Intercoxal piece of first abdominal segment angulate at middle. Second segment not as long as third and fourth together.

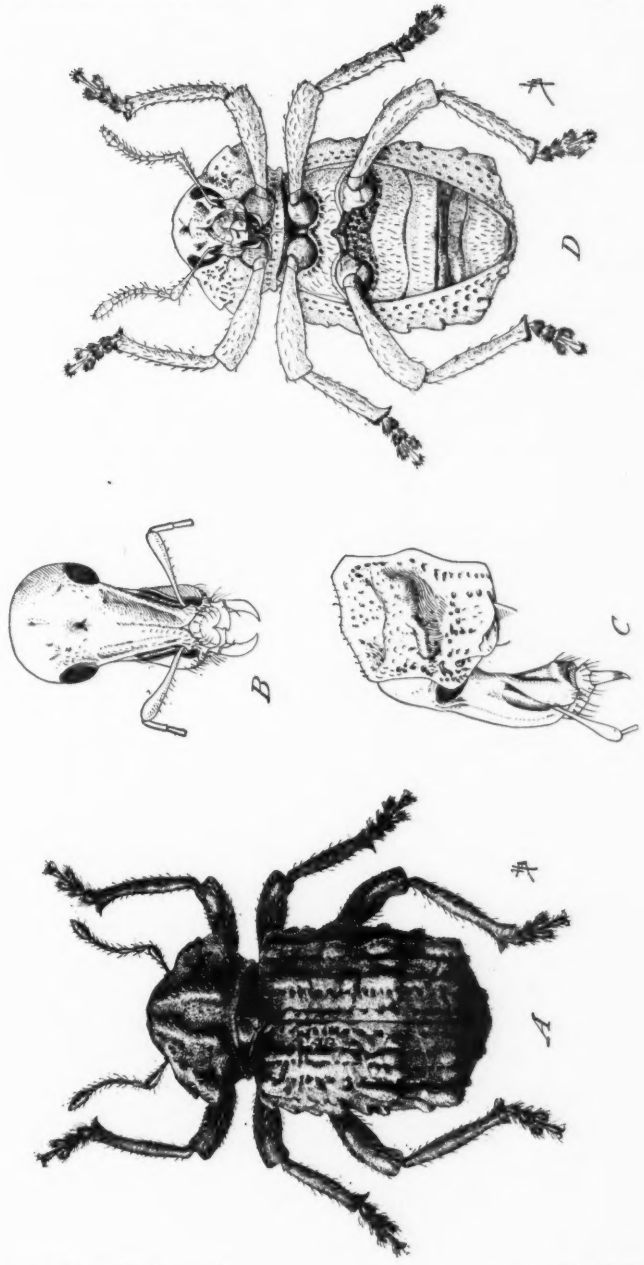
Femora dentate and canaliculate beneath. Tibiæ curved at base, strongly hooked at the apex. Tarsal claws simple.

Type.—Cat. No. 21612, United States National Museum.

PLATE 28

Trypopremnon sanfordi: Adult from Cuzco, Peru

A.—Dorsal view. Actual length 8.025 mm.
B.—Face of same. Actual length of head and beak 3.5 mm.
C.—Side view of thorax and head.
D.—Ventral view of adult.
Drawn by Mr. H. B. Bradford.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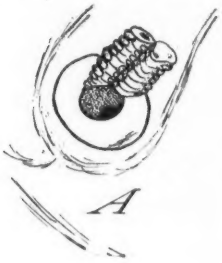
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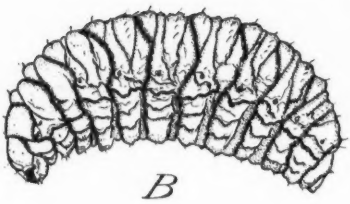
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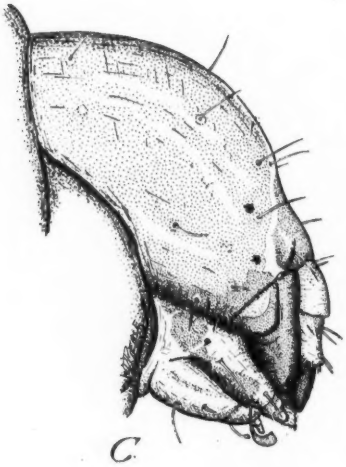
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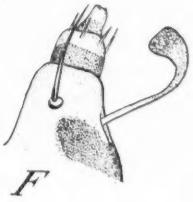
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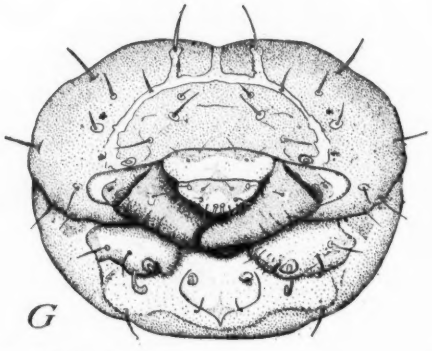
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PLATE 29

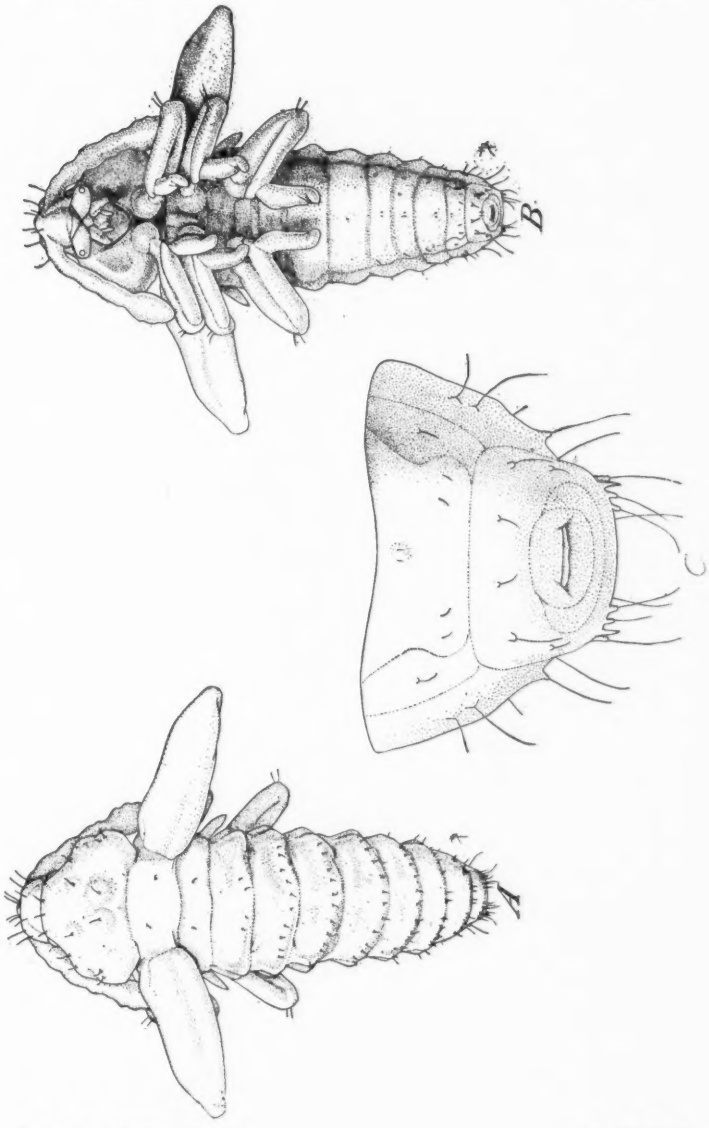
Trypopremnon latithorax: Larva from La Paz, Bolivia

A.—Prothoracic spiracle.
B.—Larva, lateral view.
C.—Lateral view of head.
D.—Right side view of apex of labium.
E.—Corresponding hair on left side.
F.—Maxillary palpiger and palpus, lateral view.
G.—Face.
Drawn by the author.

PLATE 30

Trypopremnon latithorax: Pupa from La Paz, Bolivia

A.—Dorsal view.
B.—Ventral view.
C.—Enlarged sketch of eighth, ninth, and tenth abdominal segments.
Drawn by Mr. H. B. Bradford.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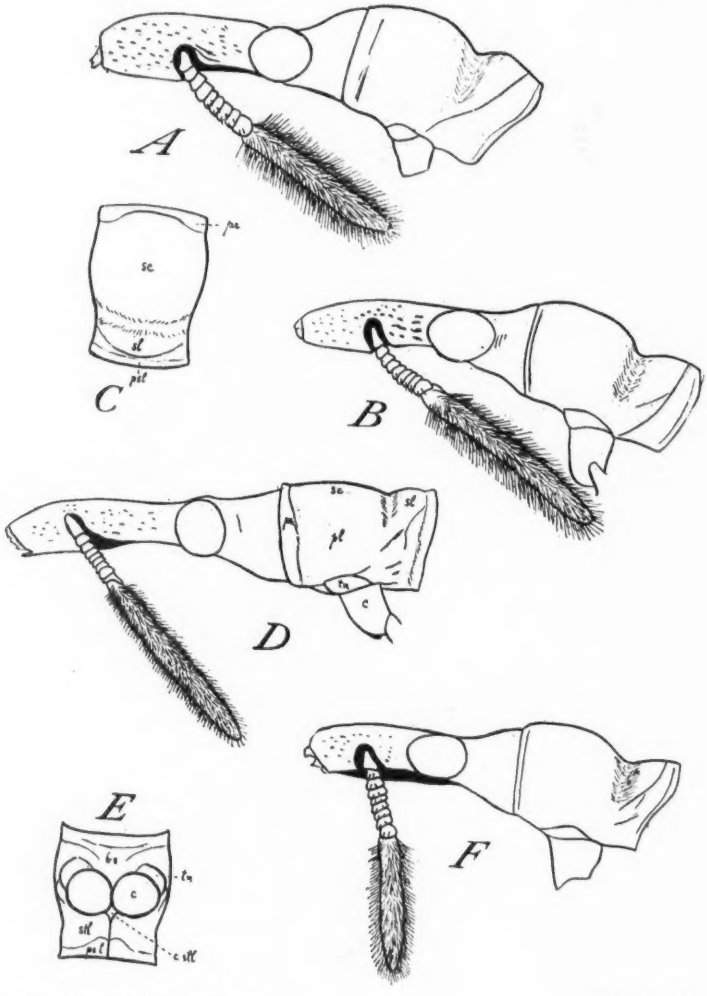
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PLATE 31

Species of the genus Cylas:

A.—*Cylas formicarius elegantulus* from Honolulu, Hawaii, side view of head and thorax.

B.—*Cylas turcipennis* from Sumatra, side view of head and thorax.

C.—*Cylas brunneus* from East Africa, dorsal view of thorax.

D.—*Cylas brunneus*, side view of head and thorax.

E.—*Cylas brunneus*, ventral view of thorax.

F.—*Cylas femoralis*, side view of head and thorax.

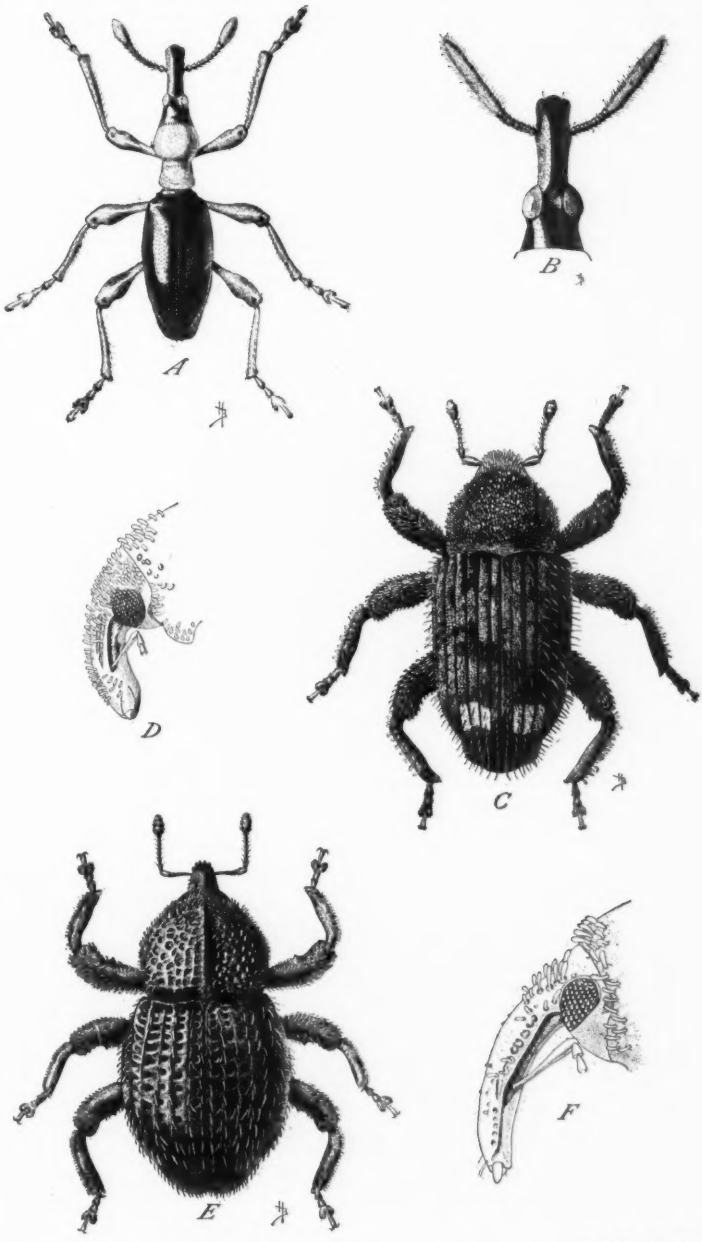
The abbreviations used on this plate are as follows: *pr*, Presegmental ring; *sc*, scutum; *sl*, scutellum; *psl*, postsegmental ring; *pl*, pleurum; *tn*, trochantin; *c*, coxa; *bs*, basisternite; *stl*, sternellum; *cstl*, centrosternellum.

Drawn by the author.

PLATE 32

Sweet-potato and yam weevils:

A.—*Cylas formicarius elegantulus*, female, from sweet potatoes, New Orleans, La.
B.—Same, head of male.
C.—*Euscepes batatae*, from sweet potatoes, Hawaii.
D.—Same, side view of head.
E.—*Palaeopus dioscoreae*, from yams (*Dioscorea batatas*), Jamaica.
F.—Same, side view of head.
Drawn by Mr. H. B. Bradford.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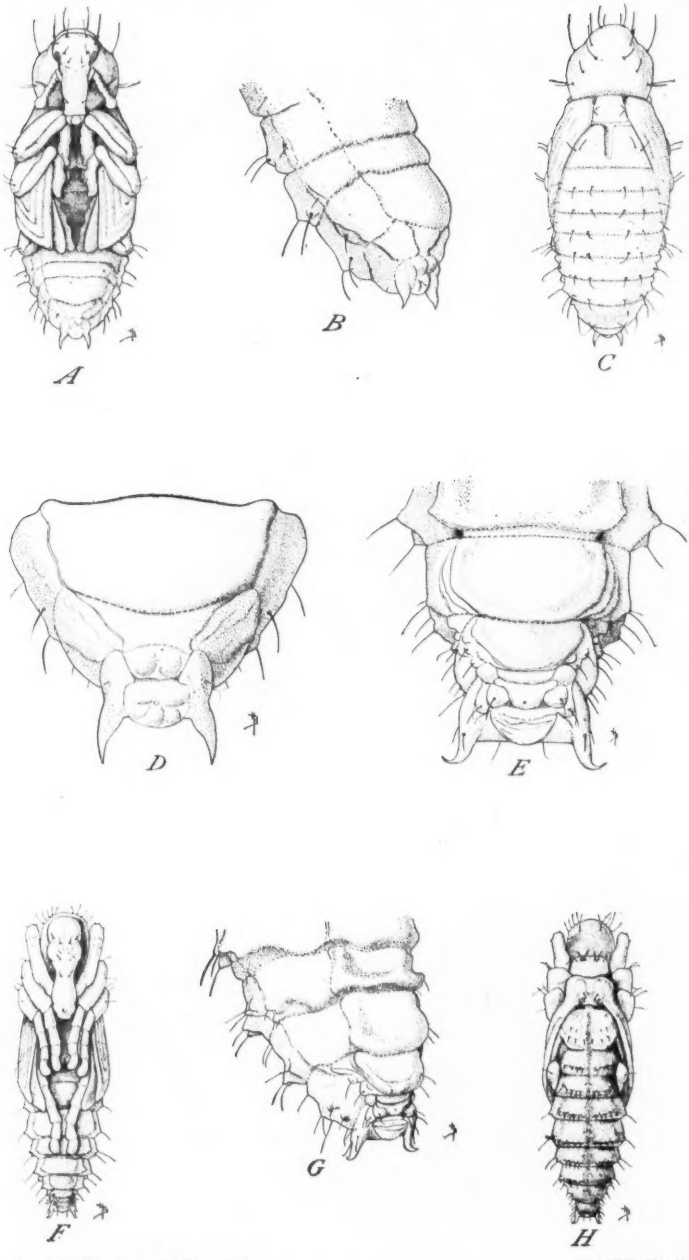
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PLATE 33

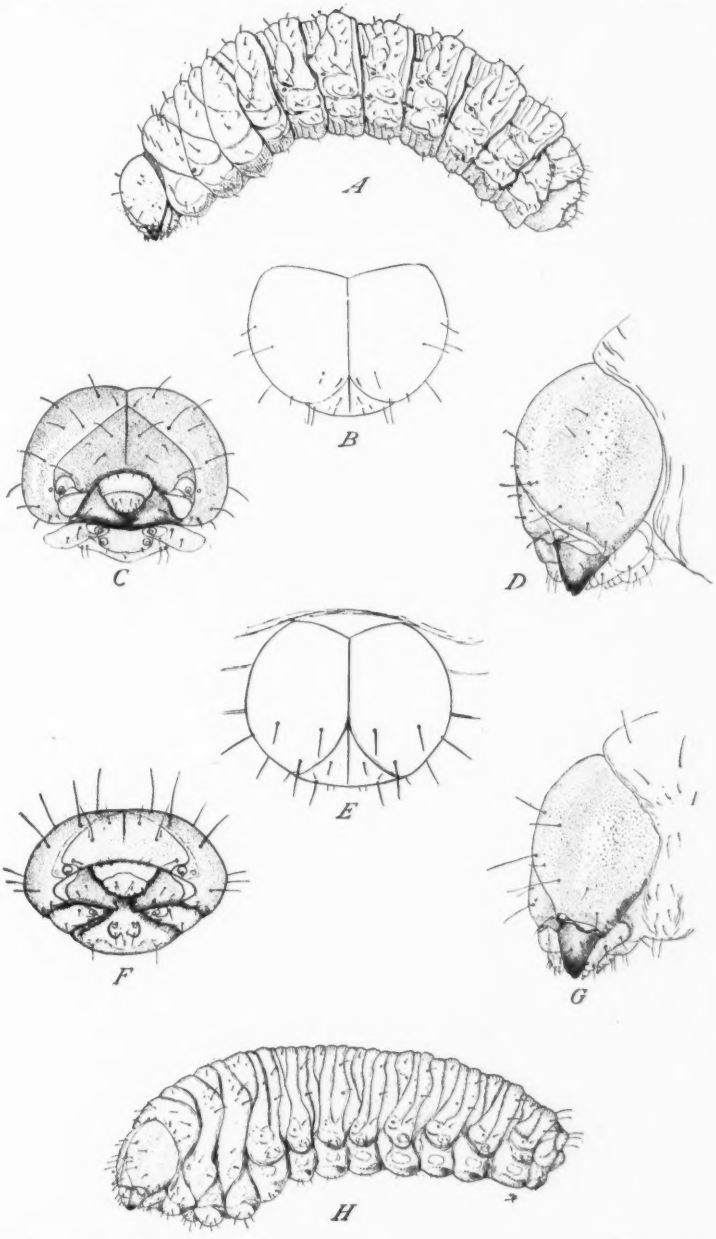
Pupæ of sweet-potato weevils:

A.—*Euscepes batatae*, Barbados, venter (length 4 mm.).
B.—Same, latero-ventral view of fifth to tenth segments.
C.—Same, dorsal view.
D.—Same, venter of seventh to tenth segments (length of this portion 1 mm.).
E.—*Cylas formicarius elegantulus*, Victoria, Texas, ventral view of sixth to tenth segments (length of this portion 1 mm.).
F.—Same, ventral view (length 6 mm.).
G.—Same, latero-ventral view.
H.—Same, dorsal view.
Drawn by Mr. H. B. Bradford.

PLATE 34

Larvæ of sweet-potato weevils:

A.—*Cylas formicarius elegantulus*, Victoria, Texas, lateral view.
B.—Same, dorsum of head.
C.—Same, face.
D.—Same, side of head.
E.—*Euscepes batatae*, Barbados, dorsum of head.
F.—Same, face.
G.—Same, side of head.
H.—Same, lateral view of larva.
Drawn by Mr. H. B. Bradford.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